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THE BRITISH JOURNAL OF METALS

Vol. 52 No. 313

NOVEMBER, 1955

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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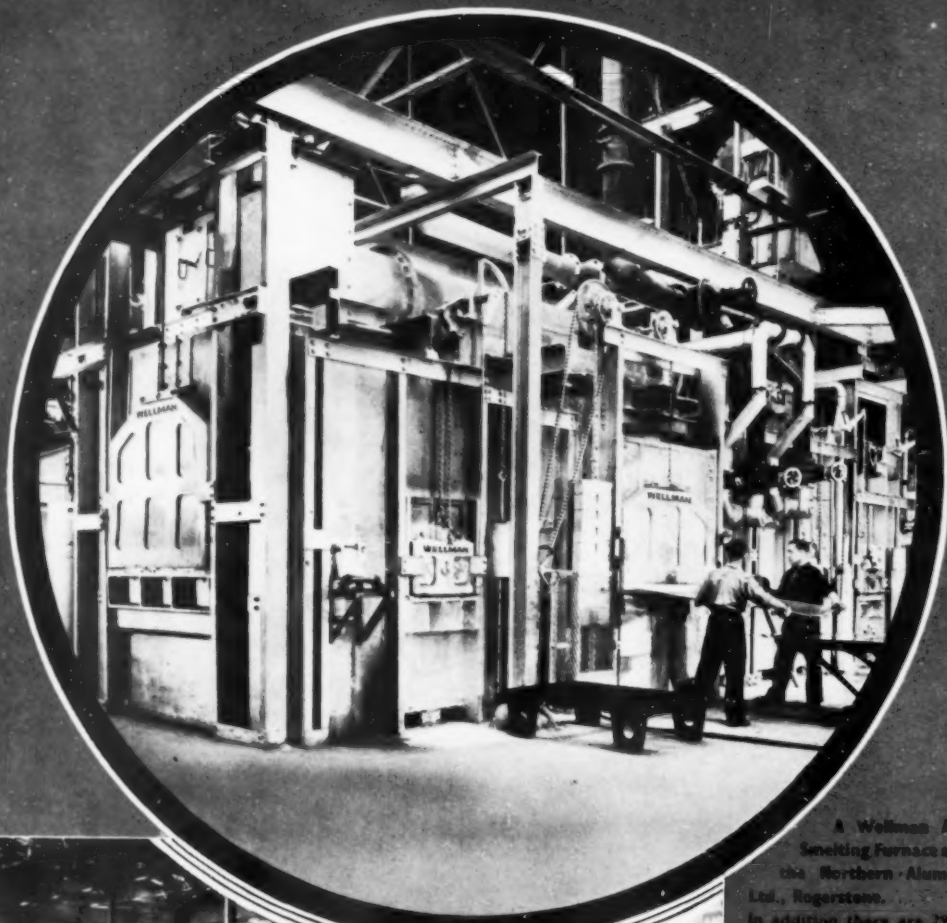
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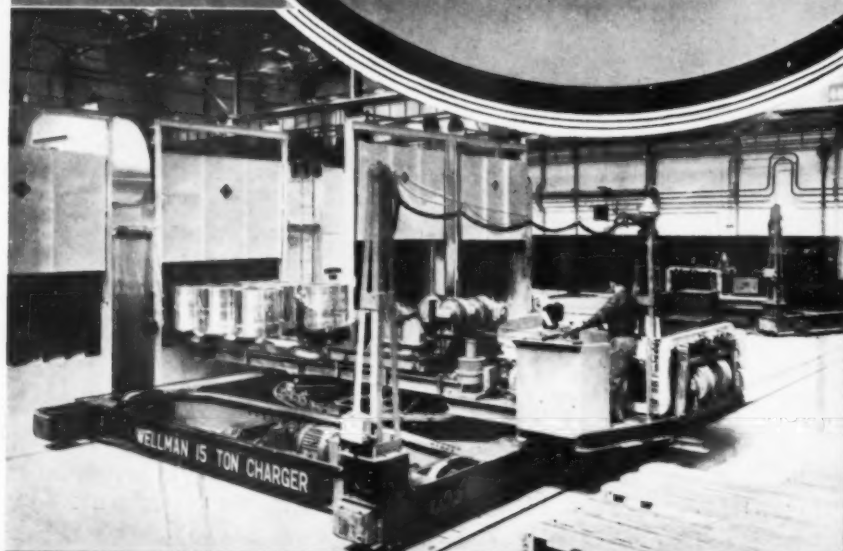
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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

NOVEMBER, 1955

Vol. LII. No. 313

Fuel Prospects

BECAUSE the United Kingdom depends for its very existence on the export of manufactured goods, it is peculiarly dependent on energy, i.e., on fuel and power. To maintain the standard of living requires that such energy should be available at a cost which is not excessive compared with the energy cost incurred by competitors in the export markets. Furthermore, every effort should be made to reduce the energy costs per unit of manufactured product. Against this background, Dr. G. E. Foxwell, C.B.E., recently discussed national fuel supply and demand in the next 25 years—apart from road and air transport based on the lighter oils—at a joint meeting of the Midland Section of the Institute of Fuel and the North Staffordshire Fuel Society.

If the trade conditions of the inter-war years were to return there would be no fuel problem, but any assessment of future requirements should take into account the claim that governments and economists have learnt the art of controlling trade fluctuations, and that full employment will continue. Moreover, the Chancellor of the Exchequer recently spoke of doubling the standard of living in the next 25 years—an objective which he believes to be possible. Assuming the maintenance of present profits on exports and terms of trade, this involves considerable increase in production—of the order of 3% compound increase per annum. In the United States there has been a 3% per annum increase in productivity—which is synonymous with production in a country such as the United Kingdom with a relatively static population—over several decades, while three times as much power is used in industry per man employed as is the case in this country. There is no doubt that increased productivity will result in a greater demand for energy, and as the trend in industrial production is towards metal and engineering products which involve a greater use of fuel and power, this demand is likely to be increased still further. Of course, improvement in the efficiency with which fuel is used will result in a slower rate of increase of fuel demand compared with the rise in production.

Dr. Foxwell concludes that if the rise in production and the development of industrial techniques continues on anything like the present scale, the rate of increase of production between 1947 and 1954 was 5.8% per annum—our energy (fuel and power) requirements may continue to increase by 2½% per annum. On the other hand, if we have to be content with a 3% per annum increase in productivity, we should budget for 1½% per annum increase in our energy demands. If increased production is achieved mainly by mechanisation, however, a figure of 2% per annum may be nearer the mark.

So much for demand—what of supply? It is expected that coal production may reach a target of 250 million

tons in the next ten years, but it is unlikely to increase thereafter by any significant amount. Moreover, as the more easily mined seams are worked out, the difficulty of getting the coal will be increased. The maintenance of a 250 million ton output may, therefore, be difficult, and will certainly involve heavy capital expenditure: in consequence, the cost of coal is likely to increase.

One aspect of the coal supply question is of outstanding importance to the iron and steel industry, namely, the future position regarding supplies of carbonisation coal for the manufacture of blast furnace coke. Although the position may not become critical during the next quarter century, it is nevertheless disquieting, and it is imperative that the gas industry should use increasing quantities of lower grade coal in order to release the better material for use by the steel industry, on which the prosperity of the country so greatly depends. Work is proceeding on the blending of lower grade coals with the better coking coals with a view to eking out supplies of the latter, and Dr. Foxwell suggests that consideration should be given to the conservation of coking coals by the use of oil, instead of using it to displace the low-grade material burnt in power stations.

In the next few years, oil fuel will be sufficient to make up the inevitable deficiencies in coal production, as indeed it is doing already. Oil consumption, used as replacement of indigenous fuels, is planned to amount to 25 million tons in 1960, but whether the amount used will require to be increased during the period 1960–1975, depends on the rate of increase of industrial production. One important aspect of the use of oil fuel that should not be overlooked is the fact that it involves costly importation, but it seems inevitable that with a continuance of increased industrial activity we shall become a fuel-importing nation. Based on present prices and the assumption that the N.C.B. will achieve its target, that coal will not be exported, and that 25 million tons of fuel oil will be required, the additional cost of fuel imports in 1960, as compared with those in 1955 will be £167 million.

Much has been said and written of the important part which nuclear power will play in the future, but it should be realised that as yet there is no experience in the operation of a commercial unit, and it is difficult to assess the likely rate of development. By about 1965, nuclear power may be sufficient to displace 5–6 million tons of coal at power stations, and may increase thereafter at such a rate that it will displace 30–40 million tons by 1975. Considerable costs will be entailed here, also, mainly in the form of capital expenditure.

On the basis of present knowledge and probabilities, Dr. Foxwell concludes, that, if the output of British coal mines reaches and maintains a figure of 250 million tons a year, our energy requirements over the next 25 years can be met by judicious selection of coal, oil and atomic energy. The importation of oil will be very costly, but home oil refineries may be able to counterbalance this by a large export trade in other oil products.

Forthcoming Meetings

24th November

Institute of British Foundrymen, Southampton Section. "Recent Developments in High-Chromium Cast Iron," by H. P. HUGHES and J. MONAGHAN. Technical College, St. Mary's Street, Southampton. 7.30 p.m.

Institution of Engineering Inspection, North-Western Branch. "The Lost Wax Process of Investment Casting," by W. N. JONES. The Engineers' Club, Albert Square, Manchester. 7.30 p.m.

25th November

Institution of Mechanical Engineers. "Developments in Mechanized Welding in the Aero-Engine Industry," by F. G. C. SANDFORD. 1, Birdcage Walk, London, S.W.1. 5.30 p.m.

North East Coast Institution of Engineers and Shipbuilders. "An Analysis of the Behaviour of Riveted Joints in Aluminium Alloy Ships' Plating," by DR. A. R. FLINT. Mining Institute, Newcastle-upon-Tyne. 6.15 p.m.

29th November

Institute of Welding, Slough Section. "Recent Developments in the Argonaut Process," by A. W. STONES. Lecture Room, The Community Centre, Farnham Road, Slough, Bucks. 7 p.m. for 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland. "Fatigue Research at M.E.R.L.," by C. E. PHILLIPS. 39, Elmbank Crescent, Glasgow. 7.30 p.m.

30th November

Institution of Engineering Inspection, West of Scotland Branch. "Elements of Quality Control," by A. KIRK. St. Enoch Hotel, Glasgow. 7.30 p.m.

Institution of Production Engineers, Worcester Section. "Hard Metal Tools," by G. COOK. The Cadena Cafe, Worcester. 7.30 p.m.

1st December

Institute of Metals, Birmingham Local Section. "Presentation of Metallurgical Information," by DR. J. W. JENKIN. James Watt Memorial Institute, Great Charles Street, Birmingham. 6.30 p.m.

Institution of Production Engineers, Gloucester Section. "Induction Heating and its Application," by D. JONES. The Belle Vue Hotel, Cheltenham. 7.30 p.m.

Institution of Production Engineers, Northern Ireland Section. "Cutting Tools and Lathe Development," by K. W. METCALFE. The Kensington Hotel, College Square East, Belfast. 7.30 p.m.

Leeds Metallurgical Society. "Radiation Damage in Metals," by DR. W. M. LOMER. Large Chemistry Lecture Theatre, The University, Leeds. 2. 7.15 p.m.

6th December

East Midlands Metallurgical Society. "Surface Effects in Fatigue," by B. HALL. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Institute of British Foundrymen, Slough Section. "Mechanization of a Small Foundry," by R. BLANDY. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Institute of Metals, Oxford Local Section. "Applications of the Dislocation Theory to Work Hardening," by DR. A. H. COTTRELL. Ballroom of the Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institute of Metals, South Wales Local Section. "Refractories and Fluxes," by DR. J. WHITE. Department of Metallurgy, University College, Singleton Park, Swansea. 6.45 p.m.

Sheffield Metallurgical Association. Joint Meeting with The Iron and Steel Institute, The Royal Institute of Chemistry and The Society of Engineers and Metallurgists. "Production Control Quantometer for Steelworks Analysis," by D. MANTERFIELD and W. SYKES. The Engineering Theatre, Sheffield University, St. George's Square, Sheffield. 7 p.m.

7th December

Institute of Welding, Manchester and District Branch. "Low Temperature Brazing—The Fundamentals of the Process and their Modern Application," by H. R. BROOKER. Reynolds Hall, College of Technology, Manchester. 7.15 p.m.

Manchester Metallurgical Society. "Forging Research at the British Iron and Steel Research Association," by P. M. COOK. Manchester Room, Central Library, Manchester. 6.30 p.m.

7th and 8th December

Institute of Welding. Joint Symposium on the Use and Welding of Aluminium in Shipbuilding. Weir Lecture Hall, Institution of Naval Architects, 10, Upper Belgrave Street, London, W. 1. 10 a.m. and 2.30 p.m.

8th December

Institute of British Foundrymen, Beds./Herts. Section. "Production of Moulds and Cores by the CO₂ Process," by A. TALBOT. Small Assembly Room, Town Hall, Luton. 7.30 p.m.

Institute of Welding, South London Branch. Joint Meeting with the North London Branch. "Measuring Productivity in Welding," by A. G. THOMPSON. 2, Savoy Hill, London, W.C.2. 6 p.m. for 6.30 p.m.

Liverpool Metallurgical Society. Joint Meeting with the North-West Branch of the Institute of Metal Finishing. "Some Aspects of Electroplating Relative to Industrial Applications," by A. W. WALLBANK. Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool. 7 p.m.

North East Metallurgical Society. "Commercial Zinc Coatings and their Performance," by R. W. BAILEY. Cleveland Scientific and Technical Institution, Middlesbrough. 7.15 p.m.

9th December

Society of Instrument Technology, Midland Section. "Temperature Measurement in the Non-Ferrous Metal Industry," by D. SMITH. Regent House, St. Philips Place, Colmore Row, Birmingham, 3. 7 p.m.

13th December

Incorporated Plant Engineers, Manchester Branch. "Corrosion Technology," by THE MOND NICKEL CO., LTD. Engineers' Club, Albert Square, Manchester. 7.15 p.m.

Institution of Engineering Inspection, South-Western Branch. "Metal Sprayed Coatings for Corrosion Resistance," by J. H. PAYNE. The Grand Hotel, Broad Street, Bristol. 7.30 p.m.

Society of Instrument Technology, Manchester Section. "Electronic Developments," by J. E. FIELDEN. Reynolds Hall, College of Technology, Manchester. 7.30 p.m.

14th December

Institute of British Foundrymen, London Branch. Joint Meeting with the London Local Section of the Institute of Metals. "Practical Implications of Research on the Casting of Non-Ferrous Metals," by E. C. MANTLE. Waldorf Hotel, London, W.C.2. 7.30 p.m.

Institute of Welding, Manchester and District Branch. "Argonaut Welding." Film and Discussion. Bolton Municipal Technical College, Bolton. 7.15 p.m.

North East Coast Institution of Engineers and Shipbuilders, Tees-Side Branch. "Stainless Steel Welding," by M. C. T. BYSTRAM. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 6 p.m.

Society of Chemical Industry, Corrosion Group. Joint Meeting with the Organic Finishing Group of the Institute of Metal Finishing. "Chromate Pigments for Metal Protection," by H. G. COLE. Chemical Society, Burlington House, Piccadilly, London, W.1. 6.30 p.m.

15th December

Incorporated Plant Engineers, Blackburn Branch. "Fabrication in a Modern Welding Shop," by R. M. WATTS. Golden Lion Hotel, Blackburn. 7.30 p.m.

16th December

Institution of Mechanical Engineers. James Clayton Lecture. "Supply Control and Combustion of Fuel to Aero-Gas-Turbines," by DR. E. A. WATSON. 1, Birdcage Walk, London, S.W.1. 5.30 p.m.

Society of Instrument Technology, Scottish Section. "Load Cells and their Applications," by G. LAYCOCK. Royal Technical College, Glasgow. 7.15 p.m.

West of Scotland Iron and Steel Institute. "Some Aspects of Blast Furnace Operation," by E. H. BALDWIN. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

19th December

Institute of Metals, Birmingham Local Section. Christmas Lecture for Schoolchildren. DR. H. M. FINNISTON. Large Lecture Theatre, Physics Department, University of Birmingham, Edgbaston. 2.30 p.m.

The Iron and Steel Institute

Successful Meeting in Scunthorpe

ALTHOUGH the iron and steel industry in Scunthorpe had its beginnings as long ago as the 1860s, it was not until last month that the Iron and Steel Institute first held a meeting there, apart from the one-day visit which took place in 1933, in connection with the meeting being held in Sheffield. With an attendance of some 470 members and guests, the hotels in Scunthorpe were unable to provide accommodation for all, and some of those taking part were lodged as far away as Lincoln, Brigg and Doncaster. This necessitated rather complex transport arrangements, but it is a tribute to the efficient way in which these and other arrangements for the meeting were organised that no difficulties arose. The Lincolnshire Iron and Steel Institute, the Scunthorpe steelworks and the parent Institute, are to be congratulated on the excellent organisation of the meeting as a whole. Certainly, Scunthorpe provided no excuse for any delay in making a return visit.

Inaugural Meeting

The meeting was opened on Wednesday morning, 12th October, by Sir Charles Bruce-Gardner, Bt., President of the Iron and Steel Institute, who pointed out that the production of pig iron was the principal feature of the local industry in its early days, and that there were only two 20-ton steel furnaces in the district at the end of the 19th century. By 1913, production of iron ore in Lincolnshire had risen to some 2½ million tons and by 1954 to 5½ million. Steel production was now running at some 2 million tons a year, a striking indication of the progress in production which had taken place.

Lieut-Commander G. W. Wells, President of the Lincolnshire Iron and Steel Institute, the hosts to the meeting, then welcomed the delegates, and at the same time reminded them that many notable advances in iron and steel production had originated in the area, including the introduction of hot metal tilting furnaces into Europe in 1902, the first mechanically-charged blast furnace in 1905, the use of mixed blast furnace and coke oven gas in 1927 and the development of the concept of thermally-balanced composite plants. More recently, flying shears had been applied to a large billet mill, and on the blast furnace side the introduction of carbon hearths had proceeded side by side with the development of large-scale ore preparation plant, which had led recently to operation with the whole of the iron content of the burden in the form of self-fluxing sinter.

The Chairman then called upon Mr. R. G. Lyttelton, immediate Past President of the Iron and Steel Institute, to present to Mr. T. F. Holmberg, Technical Director of the Oy Vuoksenniska A.B. works in Finland, the Sir Robert Hadfield Medal for 1955.

Technical Sessions

Technical sessions were held on the mornings of 12th (following the inaugural meeting) and 13th October, when papers based on experiences in the Lincolnshire iron and steel industry were presented for discussion. The first of these, by Mr. G. D. Elliot, O.B.E., was

entitled "Developments in Ironmaking at Appleby-Frodingham," and this was followed by an account by Mr. W. L. James of "The Expansion Scheme at John Lysaght's Scunthorpe Works, Ltd." On Thursday morning four papers were presented for discussion at two simultaneous sessions. At one of these, Mr. S. R. Isaac, speaking on "Steelmaking at Redbourne," was followed by Mr. J. L. Gaskell, whose subject was "Organisation for Maintenance." The Scunthorpe district has for long been the scene of opencast ironstone mining, but a few years ago an underground mine was opened by United Steel Cos., Ltd., and in the first paper of the other session Mr. C. Smith described "Underground Mining of the Frodingham Ironstone Bed at the Dragonby Mine at Scunthorpe." This was followed by a paper on "Development of Chemical Methods for the Treatment of Low-Grade Ores at Appleby-Frodingham" by Dr. L. Reeve. With the exception of Mr. Smith's, which will be published later, all these papers appear in the September, 1955, issue of the *Journal of the Iron and Steel Institute*.

Social Functions

At a reception by the Mayor and Mayoress of Scunthorpe, Councillor and Mrs. W. Albans, held at the Baths Hall on the evening of 12th October, which accorded an opportunity for members and their ladies to meet socially, the entertainment was provided by Robert Harbin, Anne Ziegler and Webster Booth, and Jimmy Wheeler. The following evening, 13th October, a Dinner and Dance was held at Elsham Hall some ten miles from Scunthorpe by invitation of the Lincolnshire Iron and Steel Institute, and by kind permission of Capt. J. Elwes, whose home it is. After dinner, the Chairman, Lieut-Commander G. W. Wells, thanked the members of his committee and the officials of the various companies for making the arrangements which had resulted in so successful a meeting, an expression of thanks which was endorsed by Sir Charles Bruce Gardner, Bt., and received with acclaim by the members and their guests.

Works Visits

The afternoons of the 12th and 13th October and the morning of the 14th October, were taken up by visits to steelworks and mines in the Scunthorpe area. These were excellently conducted and there is no doubt that the low ratio of visitors to guides made the visits far more interesting to those taking part. In the following pages a brief description is given of the plants visited.

APPLEBY-FRODINGHAM STEEL COMPANY

The history of the Appleby-Frodingham Steel Company, which produces over one million ingot tons of steel per year and employs some 10,000 people, dates from 1866 when iron was first made at the Frodingham Iron Works, steel production beginning in 1890. In 1912, the Frodingham Iron and Steel Company merged with the Appleby Iron Company, and in 1918, the company became a branch of the then newly-formed United Steel Group. Appleby-Frodingham is a fully



Courtesy of Appleby-Frodingham Steel Co.

Queen Mary and Queen Bess furnaces as seen from the high line.

integrated works occupying a site of 1,150 acres, and over £26 million have been spent on development schemes of modernisation and expansion during the post-war period. Further new developments in hand include the provision of a new turbo blower, a 300/350-ton open hearth furnace and an ingot stocking, handling and loading gantry, at a total cost of over £1½ million.

Ironmaking

There are two batteries of 66 Koppers compound coke ovens which produce 11,650 tons of blast furnace coke a week—approximately half the blast furnace plant's requirement. The other main item in the blast furnace burden is a self-fluxing mixture of Lincolnshire (20% Fe) and Northants (30% Fe) ore. Faced with a steady deterioration in the physical and chemical properties of the Lincolnshire and Northants ores, and a rising demand for iron production, increasing attention has been given to the question of ore preparation, and with the Apex plant laid down in 1939 and the Seraphim plant which went into operation last year, there are now available extensive facilities for crushing, drying, bedding and sintering, a description of which appeared in our September, 1954, issue. Oversize ore can be sent direct to the high line, so that the burden charged to the blast furnace can contain a variable proportion of ore and sinter, but since the Seraphim scheme was inaugurated the Appleby-Frodingham blast furnace plant has been operating successfully on a 100% sinter burden. Among the advantages secured by this practice are a reduced sulphur load, lower coke consumption and concentration of iron in the ore, with a consequent reduction of metallurgical load.

Of the four blast furnaces, two, known as "Queen Mary" and "Queen Bess," having hearth diameters of 25 ft. and an effective volume of 39,920 cu. ft., were commissioned in 1939. The other two were commissioned in 1954. "Queen Anne" has a 27 ft. hearth diameter and an effective volume of 42,372 cu. ft., the corresponding figures for "Queen Victoria" being 28 ft. 6 in., and 44,351 cu. ft. The hearth and bosh walls are constructed of carbon and the furnace stacks of 33-35% alumina firebrick. All the furnaces are fitted with bosh tuyeres and have three slag notches to deal with the high slag volume.

There are three hot blast stoves to each furnace, built with McKee type checkers and having a heating capacity of 160,000 cu. ft. Since the development of the 100% sinter practice, it has been found that there are no metallurgical limits to the blast temperature that can be used on the furnaces, although a consistent blast temperature of 800° C. is considered to be desirable.

Steelmaking

Both the Appleby and Frodingham melting shops use the basic open hearth process. The former was commissioned in 1927 and now comprises three 250-ton, three 300-ton, and one 300/350-ton tilting open hearth furnaces, and two mixers of 500 and 600 tons capacity. The melting shop has a capacity of 740,000 tons per annum, four furnaces using mixed gas and three using cold coke oven gas and pitch-creosote. When the Frodingham melting shop was built in 1947, it comprised two 300-ton tilters and one 600-ton active mixer, together with foundations for two more furnaces. A 300/350-ton tilter now being built will add 120,000 ingot tons to the current annual output of 315,000 tons. The mixer uses mainly mixed gas, but the furnaces are fired by cold coke oven gas and pitch-creosote. Most of the furnaces are already fully instrumented, and the remainder are in process of being converted.

Steelmaking practice at Appleby-Frodingham is based on the use of 75% of molten iron together with scrap arising from the works. In the Appleby casting pit 75- and 85-ton ladles are carried by 120-ton cranes, involving four ladles for every tapping, two ladles being supported on stands for teeming into 10 and 15-ton moulds for subsequent rolling into plates. The Frodingham casting pit is equipped with two 150-ton cranes handling 100-ton ladles, the third ladle being placed on a teeming stand. The Frodingham shop concentrates on the production of 4- and 6-ton ingots for section rolling.

Rolling

The Appleby plate mills comprise a 42 in. slabbing mill serving 10 ft. and 7 ft. plate mills, and produce over 400,000 tons of plate a year. After reheating in a battery of reversing regenerative soaking pits fired with blast furnace gas, ingots are transferred to the 42 in. two-high reversing slabbing mill which is driven by a 6,000 h.p., D.C. motor. Three furnaces of the semi-



Courtesy of Appleby-Frodingham Steel Co.

Frodingham melting shop.

continuous bogie type serve to reheat the slabs for the 10 ft. mill, two side charging furnaces supplying the 7 ft. mill.

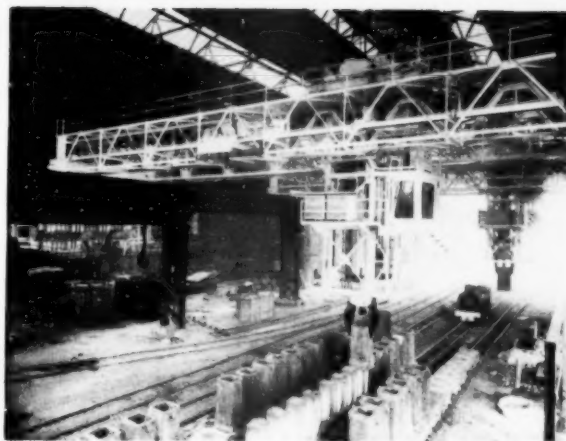
The 10 ft. plate mill is a 42 in. mill with two two-high reversing stands in line, both driven by a 6,000 h.p., D.C., motor which is a duplicate of the slabbing mill drive. The plates are rolled to between 2 in. and $\frac{3}{16}$ in. in thickness and up to 90 in. wide. Plates up to 1 $\frac{1}{2}$ in. thick are cut to size by electrically-operated side cutting shears and hydraulically-operated cross cutting shears; thicker plates are flame cut.

The 7 ft. mill is a two-stand tandem reversing mill, the roughing stand being driven by a 3,500 h.p. motor. The finishing stand is four-high with work rolls of 26 $\frac{1}{2}$ in. diameter and back-up rolls of 48 in. diameter. The mill produces about 3,000 tons of plates per week, ranging from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. in thickness, and from 24 to 78 in. wide. Shearing arrangements are similar to those for the 10 ft. mill, and a recent installation is a continuous normalising furnace 200 ft. in length, through which the plates pass prior to hot levelling.

Stainless steel plates are rolled for Samuel Fox and Co., Ltd., another branch of United Steel, and additional finishing facilities and a new de-scaling plant were erected in 1949. In 1952 a section was added for phosphoric acid pickling of mild steel.

The section mills at Appleby-Frodingham have been extensively modernised since the war, the present plant consisting of a 42 in. cogging mill, a 32 in. finishing mill and a 15 in. merchant mill. The cogging mill is a two-high reversing unit driven by a 5,500 h.p. motor, and of its 8,000 tons weekly throughput, 78% goes to the 32 in. mill and 17% to the merchant mill, the remaining 5% being supplied as blooms and slabs for re-rolling and forging. After cutting to length by electrically-operated bloom shears of the up-cutting type, the blooms destined for the 32 in. mill are re-heated in a furnace fired by pre-heated blast furnace gas.

The 32 in. mill is a three-stand two-high reversing unit consisting of first roughing, second roughing and finishing stands in line, driven by a 5,000 h.p. motor. The range of sections rolled in this mill is very wide for a unit of its size, as indicated by the fact that beams as small as 3 $\frac{1}{2}$ in. \times 3 $\frac{1}{2}$ in., and as large as 24 in. \times 7 $\frac{1}{2}$ in. are produced. The sections are cut to length by electrically-



Courtesy of John Lysaght's Scunthorpe Works, Ltd.

Stripping bay with casting bay in background.

operated saws, prior to transfer to a mechanical cooling bank.

A pusher type re-heating furnace taking billets up to 9 ft. in length, serves the 15 in. merchant mill. This mill has four three-high stands; roughing, strand finishing, oval and guide; and the rolls are driven by a 750 h.p. motor with the aid of a flywheel. An indication of the output of the mill can be gained from the size of channel sections produced, which range from 1 $\frac{5}{8}$ in. \times 1 $\frac{1}{4}$ in., to 4 in. \times 2 in. From the hot saws, the sections pass to a hand-operated cooling bank.

JOHN LYSAGHT'S SCUNTHORPE WORKS, LTD.

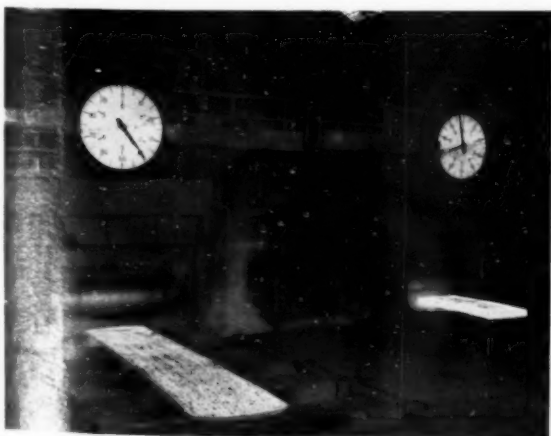
The Normanby Park Works of John Lysaght's Scunthorpe Works, Ltd., is an integrated works comprising coke ovens, blast furnaces, open hearth furnaces and rolling mills, and it was there, in 1927, that use was first made in this country of mixed blast furnace and coke oven gas as fuel in other parts of the plant.

Ironmaking

The works are adjacent to the Company's own ore field, where ironstone is extracted by the opencast method. In line with practice in other Scunthorpe works, the local stone is used in conjunction with Northants ore in the form of a self-fluxing burden: a small quantity of French ore is also used. In the ore handling department there is an ore stocking ground, a crushing plant, and a Greenawalt three-pan sinter plant capable of producing 4,800 tons of sinter per week. The ore is fed from the crushing plant and stocking ground to the blast furnace by a conveyor belt system, from which trippers divert the ore into the various bunkers.

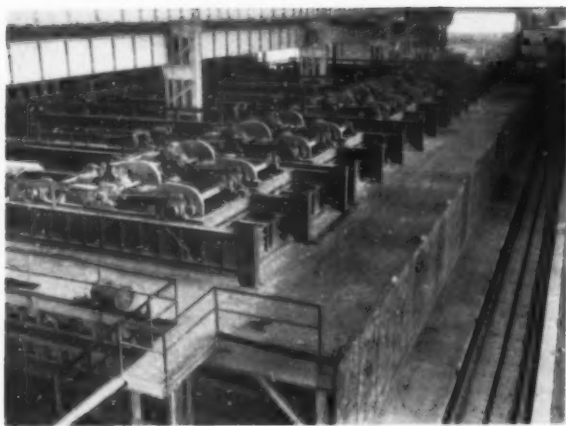
The coke oven plant comprises 92 ovens of the Woodall-Duckham Becker type. Coal to the ovens is handled through a blending plant of 7,200 tons capacity, feeding by conveyor belt to inter-service bunkers with a holding capacity of 3,800 tons, giving a total storage capacity of 11,000 tons. Coke is delivered by conveyor belt to the screening station and thence to the blast furnace bunkers. The plant also includes a by-product plant for the extraction of crude benzole, tar and sulphate of ammonia.

Of the four blast furnaces, one has a hearth diameter of 22 ft. 6 in., and the other three (one of which is not at present in operation) have diameters of 18 ft. Hot metal



Courtesy of Appleby-Frodingham Steel Co.

roughing and finishing stands of 10 ft. plate mill.



Courtesy of John Lysaght's Southwark Works, Ltd.
Soaking pits with ingot bogie track on right.

from the furnaces normally goes direct to the steel plant, but a two-strand pig casting machine and a stocking yard are installed to deal with any surplus iron which may arise from time to time. The blast furnace gas is cleaned electrostatically, in a Lodge-Cottrell plant of 10 million cu. ft. capacity, down to 0.007 grains/cu. ft.

Steelmaking

The steel plant comprises nine furnaces, of which eight are fixed open hearth units, each of 120 tons capacity, and one is a tilter of 180 tons capacity.

Hot metal requirements are catered for by two active mixers of 400 and 500 tons capacity, respectively. The furnaces use a mixture of oil and/or pitch creosote and coke oven gas. Scrap for the furnaces is handled in a scrap shed adjacent to the steel plant, and parallel with this there is a stocking ground for feed ores. Lime is supplied by belt system to a series of service bunkers.

The pit side houses three 175-ton electric overhead ladle cranes which feed the hot metal to the mixers and the prepared metal to the furnaces. They also service three mechanical teeming stands and one static stand. Each ingot car carries four moulds, teemed in pairs from double-stoppered ladles. Parallel with the casting bay is a stripping bay where two 6-ton overhead stripper



Courtesy of John Lysaght's Southwark Works, Ltd.
Six-stand, 19 in., continuous billet mill with two edging stands and flying shears.

cranes can deal with a heat of 120 tons of steel in 4-ton ingots in a quarter of an hour. The whole of the steel plant output and the handling of moulds is dealt with by one 204 h.p. diesel locomotive.

Rolling

Ingots are re-heated in twelve one-way-fired recuperative soaking pits, fired by mixed blast furnace and coke oven gas, and capable of holding 800 ingot tons. The 42 in. blooming mill is housed in a building 1,050 ft. long, along with the billet mill. The former is driven by a reversing motor of 6,650 h.p., with Ward-Leonard control. Situated between the blooming mill and the shears is a hot de-seaming plant, and a bloom bank is provided at the shears for slabs that are cogging-mill-finished.

The Morgan continuous billet mill consists of six 19 in. billet stands, with one vertical edging mill before No. 1 stand, and a second between Nos. 2 and 3 stands, for use when producing sheet bar or slab. This mill is equipped with an electric flying shear in place of the more normal steam shear, and the product is dealt with either on cooling beds, in the case of billets and slabs, or by a piling bin in the case of sheet bar and slabs, which are of a greater cross-section than can be cut in the electric shears. These latter are dealt with by means of a pendulum hot saw and collected in the piling bin.

The hot banks and billet preparation bay are serviced by four 10-ton electric overhead cranes, and whilst the majority of the product is loaded as soon as cold, there is an area reserved for cold de-seaming and inspection. The mill deals with approximately 12,000 tons of ingots per week in 17 shifts.

Parallel with the billet mill is a 12 in. rod mill, which is producing 3,200 tons of wire rod per week in sizes ranging from 5 gauge to $\frac{9}{16}$ in., 5 gauge squares, and $\frac{1}{4}$ in., $\frac{5}{16}$ in., and $\frac{3}{4}$ in. squares.

RICHARD THOMAS AND BALDWIN, LTD., REDBOURN WORKS

Like the works already described, the Redbourn section of Richard Thomas and Baldwins, Ltd., is an integrated iron and steel plant, producing in this case steel slabs, bars and billets. Ironmaking was started at Redbourn in 1872 when the Redbourn Hill Iron and Coal Co., was formed to smelt local ore into pig iron for sale on the local market. At that time the plant consisted of two small hand charged furnaces, and a third blast furnace was erected in 1909.

During World War I, more land was purchased by the Company and a fourth blast furnace, coke ovens, open hearth furnaces and rolling mills were laid down. Steel-making began in 1919 and the rolling mills commenced operation in the following year. Since 1945, two major development schemes have been completed at a cost of more than £4 million, resulting in three-blast-furnace operation, and the modernisation of much of the works. As a consequence of these developments, nearly 400,000 tons of steel and 230,000 tons of iron were produced in 1954.

Ironmaking

The present coke oven plant consists of three batteries: two of 41 Becker combination-type ovens each, which have been in operation since September, 1938 and June, 1939, respectively, and one of 19 ovens which was put into operation in July of this year. The 125 tons/hr. capacity washery installed in 1945/46 cleans small coal (minus $\frac{1}{4}$ in.) containing up to 25% ash, to give a washed

coal with an ash content of 4½%. All the coke oven gas produced is consumed in the works by the melting shop and soaking pits, and the remaining by-products, e.g., tar, sulphate of ammonia and benzole, are sold to the outside market.

Of the three mechanically-charged blast furnaces, one has a hearth diameter of 19 ft., compared with the 17 ft. 9 in. in each of the other two. Two of the furnaces have inclined hoists, but the third still has the vertical-horizontal type, which will be converted at the next relining of the furnace. The electrical equipment of No. 3 blast furnace, which was relined and blown-in in January of last year, is believed to be the most modern in the country. The blast furnace gas is cleaned by five electrostatic units, each capable of treating 2 million cu. ft./hr. and cleaning it down to 0.005 grains/cu. ft.

Steelmaking

An unusual feature of the Redbourn melting shop is that the furnaces and the casting pit are under one roof span. The shop consists of seven 100/120-ton furnaces set in line, with a 500-ton mixer in a separate bay. Six



Courtesy of Richard Thomas and Baldwins, Ltd.

New battery of coke ovens at Redbourn.

of the furnaces are of conventional double air uptake type, whilst the seventh is of single uptake design. All are worked on basic practice and fired with cold coke oven gas and pitch creosote. This type of firing was pioneered in this country at Redbourn and the Redbourn melting shop was also the first steel producing unit in the British Isles to work all-basic furnaces, as well as the first to develop the Crespi type bottom. Four of the open hearth furnaces are also equipped to burn oil. All furnaces are fully instrumented, pressure being maintained automatically and reversal controlled by the regenerator outlet temperature. Oxygen can be used on all the furnaces by lance injection, and this year a start has been made on de-siliconising, by means of oxygen, hot metal from the blast furnaces before it is poured into the mixer or sent direct to the steel furnaces.

Rolling

Setting the rolling mill are four long regenerative type soaking pits together with two multi-burner pits using cold coke oven gas and cold air. The primary mill is of the two-high reversing type and is driven by a 5,000 h.p. motor. The products of this mill are blooms 5 in. square



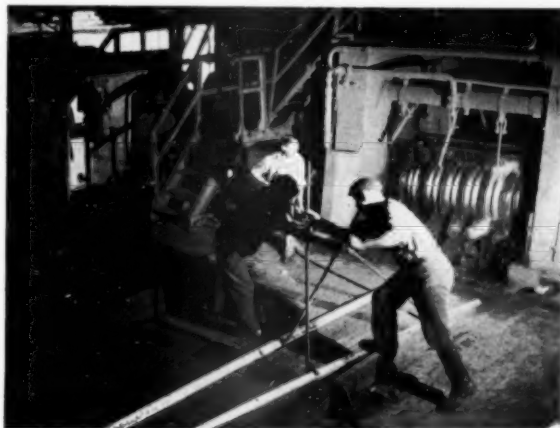
Courtesy of Richard Thomas and Baldwins, Ltd.

Charging hot metal into an open hearth furnace.

and slabs from 34 in. down to 9 in. wide. The billet mill, also of the two-high reversible type, is powered by a direct coupled three-cylinder steam engine. This mill can roll small slabs from 8 in. down to 4 in. wide, and billets from 5 in. to 2 in. square. In the case of some of the smaller sizes, e.g., 2 in. and 2½ in., the billets are dual-rolled, the bloom being reduced to a twin billet section which is subsequently split on the penultimate pass through the rolls.

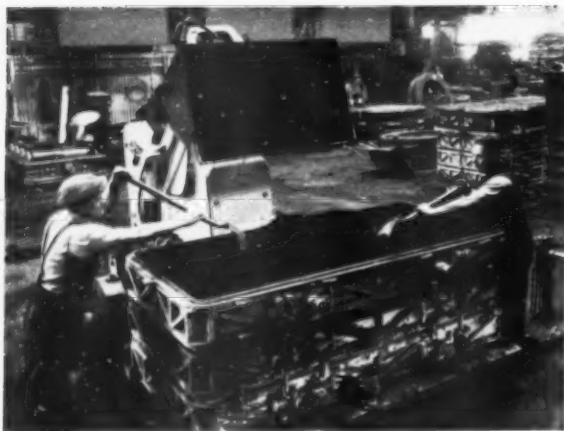
THOMAS FIRTH AND JOHN BROWN, LTD., SCUNTHORPE WORKS

Since 1917, the steel foundry of Thomas Firth and John Brown, Ltd., at Scunthorpe has been engaged in the production of carbon and alloy steel castings, the predominance being in alloy steels for special purposes. These include steels designed to withstand impact or abrasion in such applications as crusher jaws for quarry machinery. In the carbon steel range, typical examples include cranks and crankwebs for land and marine diesel engines, locomotive wheel centres, and a large variety of castings for the general engineering industry. The weight of single castings produced ranges from 4 lb. to 7 tons.



Courtesy of Richard Thomas and Baldwins, Ltd.

Billet rolling at Redbourn.



Courtesy of Thos. Firth and John Brown, Ltd.

Large moulding machines in the Scunthorpe foundry.

Moulding

The pattern shop has been completely re-equipped since the end of the war and can produce patterns for any design of steel casting required.

Considerably more moulds are made by machine than by hand. In the hand moulding section, most of the work is produced from full patterns, but sometimes sweep boards are used. The fully mechanised light machine moulding section is equipped with four jolt-squeeze pin-lift type machines for the production of mainly green sand moulds for castings from 4 to 150 lb. In the heavy machine moulding section there are nine machines, three of which are usually in reserve as spares. They include two 1,500 and one 4,000 lb. Pneulec jolt roll-over machines, two 750 lb. Pneulec jolt roll-over jolters, and Nos. 12, 16 and 20 MacDonald machines. A 10,000 lb. Pneulec jolt roll-over machine has recently been installed to produce larger moulds.

Of the two core making sections, that attached to the light moulding section is equipped with two horizontal core blowers and one bench type machine, and has a coke-fired continuous vertical drying stove. The other section has a bench type core blower, the rest of the work being hand-made. Cores are packed overnight in solid-fuel-fired batch furnaces.

Chelford, Leighton Buzzard, clay-bonded heavy Yorkshire and Mansfield red are the sands chiefly used. The bonding is partly by natural clay and partly by synthetic clay such as bentonite. No unit sand is used—all the moulds are made with both facing and backing sand. The main sand plant consists of a 5 ft. batch mill for facing sand and two 9 ft. mills for recovered sand for backing. A small kerosene-fired unit is available for drying. For the light moulding section, there is a 6 ft. mill which treats recovered sand brought from the vibrating knock-out by underground conveyor. There is another batch type 5 ft. mill handling new sand for core making and mould facing.

Steelmaking

Steel for the foundry is made by the cupola/side blown converter process, which is a flexible one producing a very fluid steel. Since the process is acid, it is essential to keep the sulphur and phosphorus contents low, and scrap selection is most important. The cupola charge is usually made up of 80% scrap and 20% hematite pig

iron. The cupolas are mechanically charged, and the molten iron is desulphurised with soda ash. It is then transferred to the converters where the "blow" takes place, lasting for about 20 minutes. Before the alloy additions are made, the slag is removed, as this produces a cleaner steel and makes for more uniform analysis. For chromium steels, an exothermic type of ferro-chrome is used to maintain fluidity in the resulting steel, whilst for 12-14% manganese and certain other alloy steels, the alloy additions are pre-melted in one of three cupolettes. To produce the larger castings, a number of heats are sometimes necessary.

Heat Treatment

This is considered a very important part of the production of castings at the foundry and may vary considerably according to the type of steel. For instance, a 12 in. thick crankweb is heat treated by a spheroidising process involving a schedule requiring some six days in the furnace. On the other hand, 12-14% manganese steel requires a single treatment followed by quenching in water. In the case of high alloy steels, annealing is often carried out for three or four days. This is followed by the dressing operation, air or oil quenching, and tempering. Of the nine heat treatment furnaces, eight are coal fired and one small one is oil fired, the capacities varying from 10 cwt. to 40 tons.

Dressing and Machining

Very large feeding heads are removed by an oxy-acetylene cutting machine capable of burning off heads up to 3 ft. 6 in. in diameter. In suitable cases the knock-off type of head is used. The two dressing shops are equipped with the usual grinding, fettling and cleaning aids. Some 25% of the output is supplied in the fully machined condition, for which purpose a wide range of machine tools is available.



Courtesy of Thos. Firth and John Brown, Ltd.

A group of typical steel castings.



Courtesy of United Steel Cos., Ltd.

A heavy duty loader transferring ironstone to a shuttle car at the heading face.

DRAGONBY IRONSTONE MINE

Excavation work began on United Steel's Dragonby Ironstone Mine in March, 1948, when it was realised that the future of ironstone mining in the Lincolnshire area would depend to an ever-increasing extent upon underground operations. The mine is situated at the northern end of the Frodingham orefield, at a point where the overburden is 60 ft., increasing steeply to over 250 ft., in thickness. After the removal of some 200,000 cu. yd. of sand and clay a huge amphitheatre was formed to the ironstone bed, and a 30 ft. wide brick-walled open gullet was made from the surface down to this bed to provide a means of access to the future mine. By the middle of 1950, the gullet had been completed and a main entry to the mine and a main return airway, each 150 ft. long, had been driven into the ironstone.

To transport the ore to the surface, 48 in. wide belt conveyors serve standard gauge 20-ton and 30-ton capacity hopper type ore wagons. The conveyors are linked by transfer stations and the first stage of development was reached when 920 yd. of conveyor belts had been installed. At this point, it was decided to provide a surge bunker and transfer station, to open up a new series of headings, and to instal a new tandem conveyor for the continuation of the main dip side development.

The conveyor for the new headings and the tandem conveyor deliver into the 20-ton capacity surge bunker, which is situated directly over a plate feeder. The speed of this feeder can be varied to deliver through an apron feeder on to the 900 yd. long conveyor according to the rate of ore input.

Electric Drilling Machines

After early experiments with compressed-air-driven boring machines for drilling the ore face, it was decided that electrically driven machines would be more economical, and a satisfactory unit was developed, mounted on a mobile chassis and driven by a 5 h.p. motor. The mine is now operated solely with these drills, although tests are in progress with a new prototype mobile hydro-electric drill. This unit can drill holes 10 ft. deep, in a head up to 24 ft. wide and 18 ft. high, at one setting.

At present, when 40 holes have been drilled, an explosion charge of 150 lb. is inserted and detonated, producing an average of 200 tons of ironstone. For load-

ing the ironstone, after blasting, one heavy duty loading machine was employed during the initial development period. This machine picks up the ironstone and transfers it to shuttle cars, after the face, roof and sides of the heading have been trimmed of loose stone. It is capable of handling 6 to 8 tons/min., though, because of time lost during movement from one heading to another, the average load handled during an eight-hour shift is between 600 and 700 tons. The present complement of rock loading machines is four. Three shuttle cars serve one loader, transporting the ironstone to the conveyor up a portable steel ramp, the load being discharged out of the open end of the car.

Electric power is supplied to the mine at 6,600 volts, 3 phase, 50 cycles. It is transformed at a surface sub-station to 3,300 volts and taken underground to a number of sub-stations at convenient points.

Since the mine began production in 1951, output has been stepped up progressively, as the figures show: 1951, 129,946 tons; 1952, 169,948 tons; 1953, 169,970 tons; 1954, 267,492 tons. It is anticipated that further workings will be opened up, utilising the valuable experience gained with the Dragonby mine, as opencast operations on the Frodingham orefield gradually result in lower yields.

B.S.I. Birmingham Sales Office

THROUGH the co-operation of the Birmingham Chamber of Commerce, the British Standards Institution has now opened a Sales Office in the headquarters of the Chamber at 95, New Street, Birmingham, 2. This development is in line with the B.S.I.'s policy of making British Standards readily available at important industrial centres. Experience in Manchester, where the B.S.I. has for long had a Branch Office (now at Coronation House, Market Street), has shown that such a facility meets a very real local need. The new office in Birmingham will, of course, maintain a full and up-to-date stock of all British Standards and associated publications, which will help to meet more effectively the growing demand for British Standards from industry and commerce, and from students and technicians.

The New Street office will operate at all normal working hours. In addition to the sales counter, it will provide facilities for the inspection of British Standards by interested persons. Normal reference facilities will continue to be available at the Public Library in Birmingham, as in many libraries in other parts of the country.

New Factory for Foxboro-Yoxall

FOXBORO-YOXALL, LTD., have acquired a 55-acre site at Redhill, Surrey, where work will shortly start on the erection of a new factory. The continued expansion of the Company's business has for some time threatened to outgrow the capacity of the three existing factories at Kidbrooke, Wandsworth and Merton. The new factory will provide, initially, a floor space of 120,000 sq. ft. with facilities for subsequent further expansion. Separate blocks housing offices, canteen, etc., will flank the factory, and staff amenities will include extensive playing fields and a sports pavilion. The new factory will, it is claimed, be the most modern of its type in Europe and will permit the Company's wide range of industrial control instruments to be produced under ideal conditions and by the most advanced manufacturing techniques.



Control of Light Forging Production

New Laboratory for Garringtons

WHEN, in 1837, John Garrington opened his first factory in Darlaston, he little realised that he was laying the foundation for what is today one of the largest and most modern forges in Europe. Nor could he have foreseen the tremendous advances which have since been made in the science of engineering, advances which have only been possible as a result of improved materials of construction. The more exacting the requirements of the designer, however, the greater is the need for prime quality in these materials. Because it is a quality conscious organisation, and because its production has increased rapidly in recent years, Garringtons, Ltd., has built a new laboratory block for the metallurgical control of forging production. With these improved facilities, the metallurgical department will be able to offer to customers a sound technical service, whether in the sphere of control or guidance.

The new laboratories were officially opened last month by Dr. T. Emmerson, Director of Research of the G.K.N. Group, whose research organisation is available to Garringtons for investigations of a long-term character. Pleasantly situated, close to the administrative offices, the new premises comprise a spacious well-lit double

storey building with a total floor area of 6,000 sq. ft. The mechanical testing and chemical laboratories occupy the ground floor, whilst the first floor houses laboratories for metallography, photography, pyrometry and experimental heat treatment. Office accommodation includes two administrative offices upstairs, together with records offices in both the mechanical testing and chemical laboratories. For the transport of samples from one floor to another a service elevator has been installed.



General view of chemical laboratory



General view of mechanical testing laboratory

Mechanical Testing

Before mechanical testing and chemical analysis, a sample from each cast of steel is checked on the Spekker Steeloscope—a simplified form of spectroscope which detects the presence of certain alloying elements and thereby ensures that the steel broadly conforms to the required composition before any further testing is carried out. Each cast of steel and non-ferrous alloy received in the works is tested for hardness, tensile strength, ductility and impact value in the mechanical testing laboratory.

For the preparation of test pieces, the laboratory is equipped with grinding, cutting, sawing, drilling and milling machines, conveniently situated near to the

testing units. Where tests are required on heat-treated material, Wild-Barfield muffle hardening and tempering furnaces are available with suitable quenching equipment.

Three machines are available for tensile testing—a 50-ton Avery, a 20-ton Amsler (used exclusively for testing aircraft materials), and a Hounsfield Tensometer. Impact values are determined on an Avery Izod machine, and an Olsen Brinell machine is used for hardness testing.

Chemical Analysis

The chemical laboratory is particularly spacious, with a floor area of 1,480 sq. ft., and is well equipped for rapid and accurate analysis. The bulk of the work is concerned with the complete analysis of each cast of steel received into the works, although a wide variety of analyses is



General view of metallurgy laboratory

called for by the activities of the Gas Turbine Division which forges aluminium alloys, aluminium bronzes, stainless steels, Nimonic alloys and titanium alloys. Additionally the compositions of die and tool steels are regularly checked and there is daily control of pickling and electroplating baths.

Apparatus of special type includes a Spekker photoelectric absorptiometer for colorimetric analysis, a Strohlein apparatus for the rapid determination of carbon in steel, and a double-unit electrochemical apparatus for the analysis of non-ferrous alloys.

Metallography, Non-Destructive Testing and Photography

The metallographic laboratory is equipped with the usual equipment for the preparation of specimens for microscopic examination, including Nash & Thompson and Apex presses for mounting specimens in plastic, and four Jackson rotating machines for final polishing. Excellent facilities are available for microscopic examination—they include a Vickers projection microscope, a Watson projection microscope, and two Cooke Troughton & Simms binocular bench microscopes. For low power examination there is a Beck binocular magnifier.

The work of the department comprises routine micro-examination of steels and non-ferrous alloys in the "as received" condition; checks on the structural condition of forgings and various products heat treated in the works; assessment of the grain size of certain steels; determination of hardenability by the Jominy and



General view of heat treatment laboratory

Rockwell Inch Methods; and sulphur printing, lead printing and macro-examination of the grain flow in forgings. Other work of a non-routine nature takes the form of investigation of shop problems, and co-operation in the development of new products and techniques.

For technical photography a Kodak specialist laboratory camera and a $\frac{1}{4}$ -plate Blumfield enlarger are available. Photomicrography may be carried out on either the Vickers or Watson projection microscopes. A spacious darkroom is fitted with a light-proof air circulation system, and is well equipped with a Kodak Duostat printer, Velox siphon print washer, Kodak flat bed glazer, and a Vardri dry mounting press.

Non-destructive testing also comes within the province of the department, the equipment including a Fel-Electric universal crack detector, and G.E.C. magnetic sorting bridges. A Westalite metal rectifier is installed for experimental work on electro-polishing and etching. Three hardness testing machines in use are of the Vickers, Rockwell and Firth Hardometer types.

Heat Treatment and Pyrometry

Considerable experimental heat-treatment work is carried out in the department, and as much of it is connected with the metallographic work the two departments are adjacently situated.



General view of pyrometry laboratory

A Wild-Barfield horizontal muffle furnace is available for hardening, annealing, normalising and carburising, whilst tempering can be carried out in a Wild-Barfield vertical forced air circulation furnace. Also installed for hardening is an I.C.I. gas-fired salt bath furnace. High temperature treatment is carried out in a Johnson Matthey platinum-wound tube furnace capable of reaching 1,400°C.

Ancillary equipment includes oil and water quench tanks, the latter being fitted with quenching fixtures for Jominy and Rockwell Inch hardenability tests. A

hot water wash tank serves to clean the work pieces after heat treatment.

The pyrometry section is responsible for the supervision of temperature control on all furnaces throughout the works. Pyrometers are standardised by skilled personnel, and patrol inspectors are engaged on the checking of operational temperatures by means of optical pyrometers. The equipment of the section includes Cambridge and Foster potentiometers, and a Wild-Barfield crucible furnace for the standardisation of thermocouples.

Ingot Cooling Investigation

AN investigation into the cooling of 15-ton ingots between teeming and stripping provided a test of the heavy duty performance of the Brown Electronik recorders used for making the necessary temperature measurements. The investigation was undertaken at the Steel Company of Wales by the Fuel Technology Section of the British Iron and Steel Research Association.

The ingots are cast in moulds resting on bogies—three to a bogie—and Fig. 1 shows the arrangement of the thermocouples on the mould and bottom plate under investigation. The thermocouples were connected to the B.I.S.R.A. multi-channel switching equipment in the protective housing at the bottom centre of the illustration, and thence by flexible leads to a cabin on the next bogie but two in which the recorders were housed (Fig. 2).

The experiments required a continuous record of temperatures transmitted by the 152 thermocouples in the test mould and bottom plate. Mould temperatures expected to change rapidly were recorded on a high speed Electronik recorder in conjunction with a 48-point switchbox, 2½ minutes being required for the complete printing cycle. The remaining mould and cap temperatures were recorded on a second high speed Electronik instrument, using 96 points of a 144-point switchbox. A medium speed Electronik recorder and a 24-point switchbox were used to record bottom plate temperatures.

As a result of these experiments, it has been possible to recommend a reduction in standing time between teeming and stripping which will lead to a saving of fuel in soaking pits and an increased mould life. This is a very satisfactory outcome of trials carried out under unusually arduous conditions.

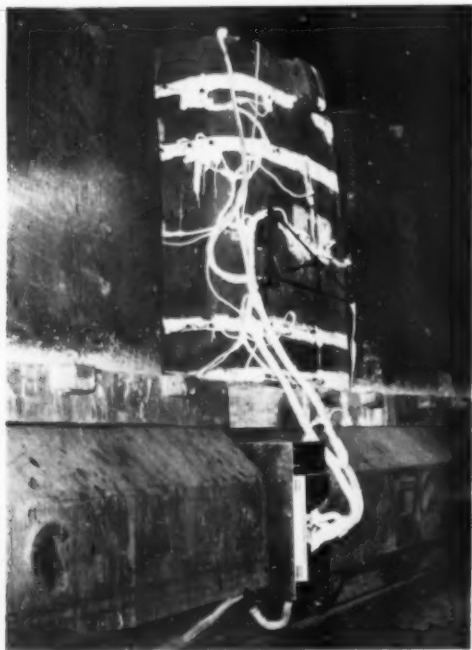


Fig. 1. Arrangement of thermocouples on the mould and bottom plate under investigation

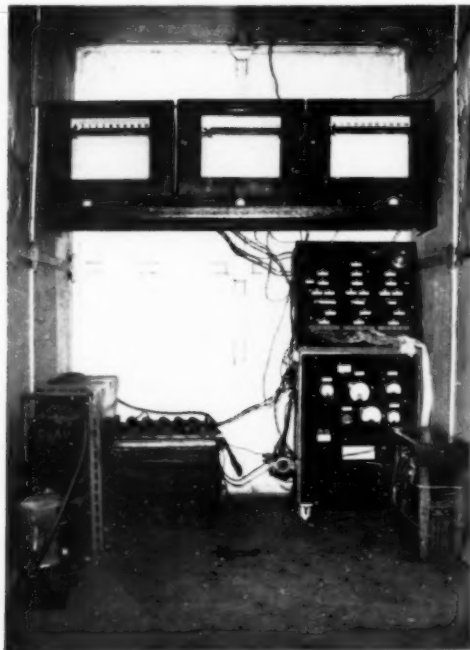


Fig. 2. Recording instruments and multi-channel switching equipment housed in bogie mounted cabin

E.S.C. Celebrates Steel Castings Centenary

From Church Bells
to Locomotive Bogie
Frames



Casting a 74 in. diameter fire alarm bell for San Francisco at Vickers' Millsands Works in 1859. The weight of the casting was 5,416 lb.

THIS year, 1955, English Steel Corporation, Ltd., Sheffield, celebrates a centenary important in the history of the British steel industry. In 1855, after a visit to Germany, Col. Tom E. Vickers, son of one of the early pioneers of the present E.S.C. organisation, introduced to Great Britain for the first time a successful method of making steel castings which a Bochum steel founder, Jacob Meyer, had discovered the previous year.

At the old Millsands Works in Sheffield belonging to

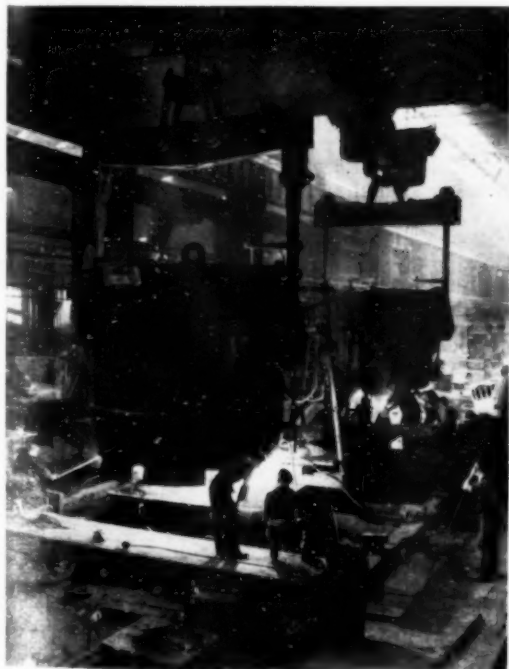
Naylor, Vickers & Co., an early precursor of E.S.C., Col. Tom Vickers, who was appointed Works Director at the age of 23, began casting Britain's first steel cog wheels and railway crossings, using a moulding compound eventually known as "Sheffield Compo," made of calcined fireclay obtained from old crucible melting pots, mixed with a small quantity of new clay to make it plastic.

His most notable venture, however, was the production of the steel bells which in the succeeding years literally rang round the world. Cheaper and more sonorous than the usual bronze bell, over seven thousand in number, weighing up to 7½ tons, had been produced by 1880. Many went to the United States, whilst others were sold as far afield as Russia, New Zealand, Syria and West Africa. More locally, within the British Isles, chimes and peals were supplied to the South Kensington Museum, the Glastonbury Astronomical Turret Clock, Knaresborough Town Hall and St. Giles' Cathedral, Edinburgh. Bell founding was discontinued by the company before the end of last century, but not before heavier steel castings, such as ships' propellers, structural and other marine castings had taken their place.

Since then, the company has developed its foundry into one of the largest and most modern in Britain. Today, the Grimesthorpe Works of English Steel Castings Corporation, one of the E.S.C. subsidiaries, produce steel castings ranging from a few ounces in weight up to 185 tons each. Amongst the heaviest of these are forging press parts and rolling mill housings, whilst lighter specialities include pressure castings for turbines, railway and mine-car automatic couplers, cast steel bogies for railway wagons, and one-piece bogie frames for carriages and locomotives.

A hundred years ago the predecessor of English Steel Castings Corporation was a pioneer in the development of cast steel products. Now, the present company is continuing the tradition by developing new methods of manufacture and new applications for steel castings, particularly in respect of one-piece bogies for railway use.

(Continued on page 235)



Casting 90 ton rolling mill housing, using two
bells, in the Grimesthorpe works of English Steel
Castings Corporation, Ltd.

Characteristics of Copper-Infiltrated Porous Iron

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The basic principles of infiltration are described as applied to iron-copper alloys in the manufacture of engineering components. The effect of iron solubility in the copper infiltrant on surface defects is considered and the performance of a copper-iron-manganese infiltrant assessed. The influence of skeleton characteristics and infiltration and heat treatment cycles on the mechanical properties of iron-copper alloys is discussed, and it is concluded that structural changes in the skeleton during infiltration can be explained in terms of alloying effects.

THE process of cold compacting metal powders, followed by sintering of the compacts to produce coherent bodies, leads inevitably to a material which contains some residual pores, and such inherent porosity results in the compacts possessing inferior physical and mechanical properties as compared with those of the solid material. For some applications porosity is very desirable, e.g., as a source of self-lubrication in bearings, but for engineering components where porosity is not specifically required, and where high strength and ductility are important, it is desirable to eliminate the residual porosity. The mechanical properties are impaired, not only by the absence of metal in the pores, but also by the stress-raising action of the pores themselves.

Porosity can be eliminated by the use of extra energy in the form of high compacting pressures and long-time high-temperature sintering treatments, possibly followed by further application of these operations to the compacts, or by a combination of processes in hot pressing. Such procedures, however, are likely to make sintered components unduly costly. An alternative approach to producing a solid, pore-free, material is that of metal infiltration, whereby a porous metallic body, i.e., the skeleton, is infiltrated with another metal of lower melting point. The latter metal, designated the infiltrant, is absorbed as a liquid by the skeleton and produces a metallic body which can be virtually solid.

The principle of infiltration has been recognised for over forty years, but the requisite conditions have only recently been detailed.¹ In general, the technique is applicable to two—or more—component metal systems having widely different melting points with no, or only limited, mutual solubility. In addition, it is important that new alloy phases, which may hinder the penetration of the infiltrating metal or alloy, should not be formed during the process. In the case where some mutual solubility does exist, the infiltration conditions are best chosen to keep the solubility effects to a minimum, and, in the case of the infiltrant, to ensure adequate fluidity. Above all, good wetting of the skeleton by the infiltrant must be ensured by the use of reducing conditions.

The binary metallic systems in which infiltration is a possibility are limited in number, and have also been listed.¹ Only a few of the possible pairs of metals are of technical importance, and of these two are currently of manufacturing interest, i.e., the tungsten-copper and the iron-copper systems. Tungsten-copper contact materials

have been fabricated by the infiltration of a tungsten skeleton with liquid copper for over thirty years, but the preparation of iron-copper materials by the infiltration technique has come into prominence only in the last decade.

Both iron and copper are of real interest in powder metallurgy, owing to the availability and relative cheapness of their powders. Relatively economic compacting pressures, sintering temperatures, and atmospheres can be used, and, in view of the fact that such materials are amenable to heat treatment, good mechanical properties can be developed. Accordingly, the infiltration process is of outstanding interest, since it favours the fabrication of high strength compacts by the powder metal process using economical equipment and techniques.

The Iron-Copper System

The details of the iron-copper system are by now well established, and Fig. 1 reproduces those portions of the equilibrium diagram that are relevant to the infiltration process. It will readily be appreciated that the system satisfies the basic conditions necessary for infiltration, in that the melting points of pure iron and copper are widely different (1,527° C. and 1,083° C., respectively), and that only limited solubility exists between the two metals. In addition, no phases of high melting point exist which might obstruct the continuity of the infiltration.

At room temperature, iron and copper are virtually immiscible, but intersolubility increases at higher temperatures. The solubility of iron in α -copper gradually increases with temperature until at 1,094° C., 4% can be absorbed, the dissolved iron having raised the melting point of copper from 1,083° C. to this temperature. At 1,094° C., a peritectic reaction results in a reduction in the solubility of iron in molten copper to 2.3%. At the iron-rich end of the diagram, α -iron gradually absorbs copper as the temperature increases to the eutectoid transformation temperature of 833° C., whereupon γ -iron containing 5% of copper is formed. The solubility thereafter increases with temperature until, at 1,094° C., approximately 8% of copper can be absorbed by γ -iron. Above 1,094° C., the respective degrees of solubility in both the γ -solid solution and the liquid copper alloy increase further with temperature.

It will therefore be seen that at the minimum temperature which must be used in the infiltration process, i.e., 1,094° C., true equilibrium conditions are represented

by a molten copper alloy containing about 2.3% of iron and solid γ -iron containing 8% of copper.

PART I.—THE ROLE OF THE INFILTRANT

Pure Copper as an Infiltrant

In the infiltration process it is necessary to prepare accurate repeat weights of the infiltrant metal, since it is important that the amount of infiltrant shall be precisely allied to the available pore volume of the skeleton. If too much infiltrant is present, excess metal will remain on the outside of the skeleton, and if too little is used, inferior properties will ensue. When equipment is available, it is very convenient to prepare the requisite quantities of infiltrant by compacting the particular metal powder. Since the material is to be melted, it is not always necessary to sinter such compacts; they can be used in the un-sintered condition, i.e., in the green state.

Copper powder of high purity is readily prepared by electrodeposition, and is widely used for powder metallurgical applications. Infiltrant compacts are, therefore, conveniently formed from such powders, and their use gives rise to interesting effects.

Skeletons were prepared from grade MH100 Swedish sponge iron powder compacts sintered in a partly burnt town's gas atmosphere (exothermic gas) for approximately 15 minutes at 1,100° C. to a density of 5.9 g./cc. (i.e., 75% of solid density). The infiltrant consisted of a green copper powder disc formed in the same die, and of sufficient weight to fill 90% of the calculated pore volume. The infiltration heat treatment was carried out in exothermic gas, and consisted of heating the skeleton and infiltrant to 1,110° C. for approximately 10 minutes. The resulting infiltrated blank showed deep erosion channels in the top surfaces where the infiltrant compact had been in contact, and it was apparent that some of the iron of the skeleton had been eaten away. Such is the

"erosion" phenomenon which has been reported by various observers.

Copper-Iron Infiltrants

A quantity of the electrolytic copper powder referred to above was melted in a small crucible held under exothermic gas at 1,110° C. The molten copper was then stirred with an iron rod for up to 4 hours, in the course of which a portion of the iron rod dissolved in the melt. The copper alloy was subsequently analysed and found to contain 2.43% of iron. This value is in approximate agreement with that expected from the equilibrium diagram (see Fig. 1).

The requisite quantity of this copper-iron ingot material was employed as an infiltrant under conditions of temperature and atmosphere identical with those under which it had been prepared, and, therefore, under conditions similar to those used for the copper infiltration referred to above, i.e., 10 minutes at 1,110° C., using exothermic gas. No erosion whatsoever could be observed, and there were no signs of the passage of the infiltrant through the surface of the skeleton. It is to be presumed, therefore, that the erosion phenomenon marks the saturation of the molten copper by iron, the latter, of course, being taken from the skeleton surface.

To demonstrate further the connection between erosion and solubility effects, an infiltration test with the same copper-iron alloy was carried out at 1,150° C. under otherwise identical conditions. On this occasion slight erosion was evident; indeed, this is to be expected since the equilibrium diagram indicates that the solubility of iron in molten copper steadily increases above 1,094° C. Similarly, infiltration tests with prepared copper ingot alloys containing slightly less than 2.43% of iron gave rise to erosion at 1,110° C. (and 1,150° C.), whilst alloys containing more than this level of iron showed no erosion at 1,110° C.—in fact, they showed a slight and adherent metallic deposit: this, on removal, was shown to be iron. The presence of such a deposit of iron can be explained by the presence in the molten copper of free iron, in excess of the equilibrium level, which is filtered out during infiltration. Higher infiltration temperatures were found to lead to the elimination of this deposit.

The above observations bear on the solubility effects in the infiltrant, and clearly show a correlation between surface finish, manifest as erosion or iron deposit, and the state of equilibrium in the molten copper infiltrant. Parallel solubility effects in the solid skeleton material occur at the same time, and will be discussed later in some detail.

Copper-Iron Powder Infiltrants

As mentioned previously, there are some advantages in having the infiltrant metal in powder form, in addition to which it is desirable in some cases to make the infiltrant the same shape as the skeleton compact. In this case, the same die may be used, and the infiltrant metal must be in powder form. The use of a pre-alloyed copper-iron powder of the equilibrium composition previously ascertained, therefore, commends itself. Such a material, prepared by the atomisation process, can be successfully used as an infiltrant, and will give a performance equal to that of the ingot material.

As an alternative to using a pre-alloyed powder, it is feasible to prepare a copper-iron material by mixing copper and iron powders together in the requisite proportions. There is an advantage in this approach,

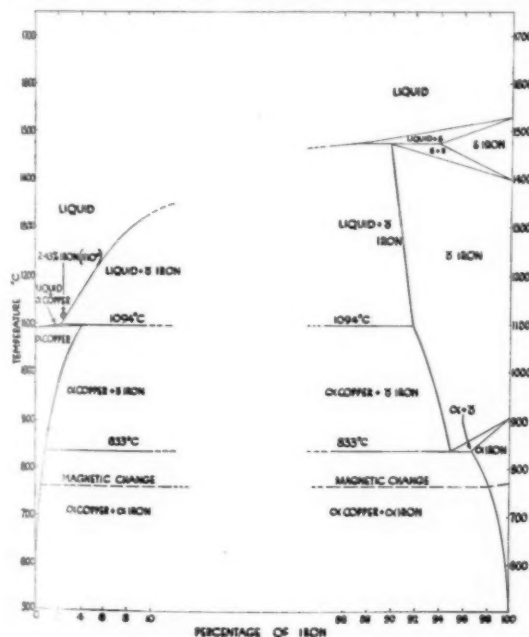


Fig. 1.—Copper-iron equilibrium diagram.

TABLE I.—DISTRIBUTION OF ELEMENTS IN COPPER-MANGANESE-IRON INFILTRATION

	Weight g.	Chemical Composition			Weight of Manganese Present g.
		Cu %	Mn %	Fe %	
Skeleton Compact	35.075	Nil	0.025	Sol., Bal.	0.009
Infiltrant Compact	8.711	90.33	4.50	4.74	0.392
	Total Weight 43.786				
Infiltrated Compact	42.376	15.96	0.043	Not Determined	0.016
Residual Deposit	1.557	63.08	24.59	6.88	0.383
	Total Weight 43.933	(Total 94.55%)			

namely, the ability to make up accurate mixtures of the two metals, and copper-iron mixtures have been prepared by mixing electrolytic copper powder and very fine iron powder, such as carbonyl. It is desirable to use the finest grades of iron powder in order to approach near to a homogeneous condition.

Infiltration tests with green infiltrant compacts pressed from a copper powder mix containing 2.43% of carbonyl iron powder have been carried out under conditions identical with those previously described. The surface finish in this case exhibited both erosion and iron deposit to a minor degree, and this seemed to reflect the essential heterogeneous nature of the powder mix. It should be pointed out that the time of heating up to the infiltration temperature (1,110° C.) was short, and that little homogenising would occur prior to infiltration.

The application to the infiltrant compacts of a pre-sintering treatment at 1,050° C. had the effect of reducing both the erosion and deposit phenomena, indicating an advance towards a condition which is associated with a perfectly homogeneous alloy. It will be understood that alloying of the copper and iron can take place particularly effectively at this temperature, owing to the increased solubility of iron in solid α -copper below the melting point of 1,094° C. A minimum period of 30 minutes was found essential to bring about a satisfactory degree of alloying for reasonable surface finish.

From the foregoing, it will be appreciated that by making due allowance for solubility effects it is possible to produce infiltrated compacts having no surface defects. It is also clear from the evidence presented, however, that for any one infiltrant composition there is one temperature at which perfect surface finish is achieved, and that to depart from this temperature would lead to an incidence of surface defects. The factor of temperature limitation is important in that flexibility is desirable, e.g., as a means of controlling dimensional changes, and this, together with the need, since the iron content is critical, for precise control of composition, must be accepted as inherent difficulties in using straight copper-iron infiltrants.

Copper-Manganese-Iron Infiltrants

The use of a copper infiltrant which contains iron and manganese has been referred to in the technical and patent literature.^{2,3} Such a material, nominally containing 5% iron and 5% manganese, has been prepared and some tests have been carried out. The material was

prepared in pre-alloyed powder form by the atomisation process.

Very little published information is available on the ternary copper-manganese-iron system. The binary copper-manganese system shows a wide range of solid solubility of γ -manganese in copper, both of which have face-centred cubic lattices, and the melting point of copper is depressed by up to 35% of manganese. The liquidus surface temperature for a 5% manganese alloy is approximately 1,020° C. The manganese-iron binary system also shows a considerable degree of mutual solubility between the γ -phases of iron and manganese. It is probable, therefore, that the ternary alloy of 90/5/5 copper-manganese-iron composition is a single phase alloy at temperatures approaching the melting range, and also that the liquidus of the alloy is lower than 1,094° C.

Infiltration tests were attempted exactly as previously, but at a temperature of 1,060° C., i.e., 50° C. lower than hitherto, using an exothermic atmosphere. No fusion of the infiltrant could be detected, and it appeared to be seriously oxidised: the oxide was green. The infiltration temperature was progressively raised, and not until a temperature of 1,100°/1,110° C. had been reached could appreciable infiltration be observed. Under these latter conditions, it was noted that a deposit, which was loose, remained outside the infiltrated blank, and that the surface finish was of a high quality. Neither erosion nor any form of adherent deposit was evident. The residual deposit appeared to be largely composed of oxide, was slightly magnetic, and, upon being fractured, appeared to hold some metallic copper.

In view of the oxidised nature of the deposit, further infiltration tests were undertaken using a more reducing atmosphere than exothermic gas. The latter contained 5% CO₂ and was known to be of a reducing and decarburising nature with respect to iron and copper. Cracked ammonia—consisting of 75% hydrogen and 25% nitrogen with a dew point of -40° C.—and cylinder hydrogen were used as alternative atmospheres, and the result was in general similar to that in exothermic gas. Residues which were loose, slightly magnetic and largely oxide, together with good surface finishes, were observed.

Distribution of Manganese and Efficiency of the Process

To elucidate the matter further, specimen infiltrant and skeleton compacts which had been processed in an exothermic gas atmosphere at 1,110° C. for approximately 10 minutes were analysed, and the results are set down in Table I. The weight of infiltrant was sufficient to fill 65% of the calculated pore volume of the skeleton, which had a density of 5.90 g./cc.

It will first be observed that the residue represents a significant, though minor, proportion of the original infiltrant compact, and that the major part of the residue is copper, plus a high proportion of manganese and a minor amount of iron. This loss of copper from the infiltrated compact is reflected in the relevant weights, and it is possible to assign an efficiency to the infiltration process by comparing the increase in weight of the skeleton with the amount of infiltrant actually taken (8.711 g.). Thus the efficiency will, in the above case be

$$\frac{(42.376 - 35.075)}{8.711} \times 100 = 84\%$$

It will be noted that there has been an overall increase

in the weight of the components during the process, and, since this is no doubt connected with the oxidation of the infiltrant which took place, it is not unexpected that the analysis of the deposit adds up to only 94.55%.

The distribution of the manganese is particularly interesting. The greater part of this element remained outside the skeleton, and only 0.007 g. entered via the infiltrant. Of the total amount of manganese contributed by the infiltrant, 0.392 g., only 2%, has infiltrated, and the remaining 98% has remained in the residue. Such a distribution amounts to a virtual elimination of manganese, from the infiltrating metal. In a similar type of test in cracked ammonia, the efficiency was observed to be 86%, and the manganese content of the infiltrated compact rose to 0.33%. This corresponded with approximately 30% of the element entering the infiltrating metal and 70% remaining in the residue. The rejection of the manganese, therefore, was not so high in this case, where the atmosphere was of a more reducing character.

The question of the efficiency of the process was further examined. Tests were carried out in exothermic gas using various quantities of infiltrant, and the graph in Fig. 2 presents the results. Infiltrant compact discs were placed alternatively on top or beneath the skeleton, and the nominal percentage filling of the pores varied from 70 to 115%. The efficiency varied between 80% and 90%, and was highest for those compacts placed beneath the skeleton. Undoubtedly the better contact achieved by the greater weight of the skeleton explains this effect. The skeletons were normally observed to grow during infiltration and this accounts for the unusual fact of recording, in one case, an actual percentage pore filling of 105%.

Mechanism of the Process

In order to understand the copper-manganese-iron infiltration process, it is important to consider the stability of the respective oxides under the conditions obtaining during the infiltration cycle. The free energies of formation ($-\Delta G$) at 1,100° C. of the lowest oxides are as follows:⁴

CuO: 38 Kg. cal./g. mol. of oxygen
FeO: 80 Kg. cal./g. mol. of oxygen
MnO: 133 Kg. cal./g. mol. of oxygen

It is apparent that CuO is the least stable and MnO the most stable of the oxides. The latter is remarkably stable and compares in this respect with Cr_2O_3 , which has a $-\Delta G$ value of 135 Kg. cal./g. mol. of oxygen at 1,100° C. Consequently, it is feasible that the infiltration conditions could maintain copper and iron in the reduced condition whilst promoting oxidation of the manganese.

Presumably oxidation of the manganese can proceed from an early point in the infiltration cycle. Towards the final stages, the element is removed from the metallic state, and the oxide so formed creates *in situ* a form of porous skeleton. It is considered that this porous framework serves as a reservoir in which the copper, iron and any remaining metallic manganese can fuse and attain equilibrium, most of this material subsequently passing into the adjacent skeleton, leaving no surface defect. Excess iron is retained in the deposit, and the oxide nature of the reservoir itself prevents adhesion to the skeleton surface.

The alloy powder has been examined under the microscope, and a slight degree of heterogeneity has been noted: in fact, a small proportion of the particles are magnetic.

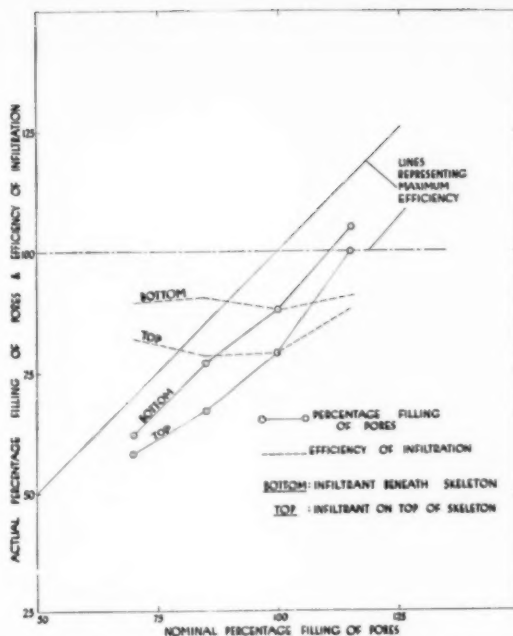


Fig. 2.—Efficiency of copper-manganese-iron infiltration.

However, the greater part of the manganese and iron appears to be fully alloyed, and consequently, preferential oxidation of the manganese must be operative. Calculation shows that the increase in weight of the above components corresponds to the formation of MnO and MnO₂, approximately in the ratio of two-thirds of the former to one-third of the latter oxide.

Conclusions

From the evidence presented, it is suggested that, particularly in the case where an exothermic type of atmosphere is used, it is true to say that a copper-iron and not a copper-manganese-iron infiltration is essentially achieved. In the case of tests in cracked ammonia, elimination of the greater part of the manganese from the infiltrant is again involved, but to a lesser degree.

It will be appreciated that the use of a copper-manganese-iron infiltrant ensures a defect-free surface finish at the cost of some loss in the efficiency of the transfer of infiltrant. Whereas the efficiency of a comparable copper-iron powder infiltrant would be virtually 100%, it is generally 10–20% lower for the ternary alloy. In many cases, the question of surface finish may be more important than the factor of efficiency, but, in addition, it will be appreciated that the use of an external oxide reservoir, in which equilibrium is self-adjusting according to temperature, does not require a fixed temperature to produce a defect-free surface, as is the case with a copper-iron infiltrant. The choice of infiltrant for any particular component must be made in the light of these various considerations.

PART II.—THE ROLE OF THE SKELETON

The skeleton is the basic framework of an infiltrated compact, and is necessarily of great importance in determining the physical and mechanical properties of the final product. The skeletons referred to in the previous section were compacted from iron powder in

TABLE II.—PROPERTIES OF SOLID IRON-COPPER ALLOYS.

Copper Content (%)	Ultimate Tensile Strength (lb./sq. in.)	Yield Point (lb./sq. in.)	Elongation (%)	Reduction of Area (lb./sq. in.)
Annealed				
Nil	51,000	33,000	30	60
5	70,000	55,500	21	46
8	71,500	59,500	17	25 (approx.)
As-Forged				
Nil	60,000	52,000	28	68
5	115,000	104,000	11	30
8	148,000	135,000	Nil	Nil

which copper was absent, and sintered prior to the infiltration part of the process. During this latter stage the iron skeleton is in contact with molten copper-iron alloy and, since approximately 8% of copper can be absorbed by γ -iron at this temperature, some diffusion of copper into the skeleton metal is bound to occur. It must be borne in mind, however, that, since the skeleton material remains solid, the rates of diffusion will be low as compared with those in the molten phase. The phenomenon of erosion demonstrates the high rates of diffusion which are operative in the latter condition.

Influence of Copper on the Properties of Iron

Copper has long been added to iron-base metals in order to increase their strength and corrosion resistance. In addition, such alloys can be heat treated and their strength additionally improved by means of a precipitation hardening process. Up to 2.5% of copper is added for these purposes, and it will be seen from Fig. 1 that the change in solubility of copper in α -iron with temperature lends itself to this end.

For the purpose of infiltration, the influence of copper contents up to 8% must be considered, and Table II presents the properties of some annealed and forged solid iron-copper alloys.⁶ It will be noted that the addition of copper in the case of both the annealed and the as-forged alloys brings about an increase in the strength and a reduction in the ductility of the material, and that the effect is progressive up to the highest copper content of 8%. Thus, it is evident that the diffusion of copper into iron will bring about a change in the mechanical properties of the iron, and that the degree of change will depend upon the amount of copper absorbed.

Influence of Heat Treatment on Iron-Copper Alloys

In order to study the influence of heat treatment upon iron-copper material in a quick and simple manner, it was desired to measure the heat treatment effects in terms of indentation hardness values. No solid alloys were available for this work, and since porous compacts, which were available, do not lend themselves to critical indentation hardness testing, it was decided to utilise a number of infiltrated compacts which had been prepared, in the course of experiments previously described, by copper-iron infiltration carried out in a conveyor furnace. The skeletons were sintered to a density of 5.9 g./cc. from MH100 iron powder; the amount of infiltration was 75% and they contained no carbon.

The aim of the heat treatment experiments was to estimate the influence of various types of heating and cooling cycles to which infiltrated compacts may be subjected in the course of manufacture, and/or which could be subsequently applied to improve their properties. The precipitation-hardening heat treatment for

solid iron-copper alloys which contain up to about 2.5% copper is well established, and consists essentially of a solution treatment in the region of 800° C., followed by an ageing treatment. It will be seen from Fig. 1 that, at 800° C., approximately 2.5% of copper can be dissolved in α -iron, and it is widely reported that a cooling rate of 25° C./min. or greater will suffice to retain this copper in solution. Ageing temperatures in the range 400–550° C. are customary, and for a 500° C. treatment maximum hardness is reported to be attained after 4 hours. Accordingly, such a treatment has been applied and the results obtained by water quenching from 800° C., followed by ageing, are presented in Table III. It will be noted that an improvement in hardness over the initial value did, indeed, occur.

A similar compact was further heat treated by water quenching sections from 900° C. and 1,050° C., and it will be seen that higher hardness values (124–126) were observed. These specimens were, of course, quenched from the γ -iron region, but from below the melting point of copper. Air cooling from the same temperatures achieved the same degree of hardening, whilst a furnace cooling cycle resulted in the lowest hardness of 71 being recorded. Ageing treatments applied to a compact water quenched from 900° C. did not, in fact, bring about an improvement, but resulted in a slight reduction in hardness. It was apparent, therefore, that the greatest hardening effect in this material could be obtained by simply cooling fairly rapidly from a temperature of 900° C. or above, rather than by following the established precipitation-hardening treatment based on solubility effects in α -iron.

The matter was further pursued in order to ascertain the influence of heat treatment on tensile strength and ductility, and Table IV sets out the results obtained. The compacts were moulded in the form of tensile specimens of the shape specified by M.P.A. Standard 10-50, and B.S. 2590. In both the sintering and the infiltration treatments the compacts were soaked for approximately 10 minutes at 1,120° C. in exothermic gas and cooled as described.

Considering the results in the table, it is evident that the strength of the straight iron skeletons is not susceptible to the rates of cooling from their sintering temperature. The infiltrated compacts, however, show a marked effect of rate of cooling upon both strength and ductility and, in particular, a wide range of elongation is evident. It is interesting to note that the conveyor furnace gives strengths and elongations which are intermediate be-

TABLE III.—THE EFFECT OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF INFILTRATED COMPACTS

As-Infiltrated Hardness (Brinell, 10 mm., 500 kg.)	Heat Treatment	As-Heat Treated Hardness (Brinell, 10 mm., 500 kg.)
83	Water quenched from 800° C.	99
	Water quenched from 800° C. and aged 2 hours at 500° C.	104
	Water quenched from 800° C. and aged 4 hours at 500° C.	106
83	Water quenched from 900° C.	124
	Water quenched from 1,050° C.	126
	Air cooled from 900° C.	124
	Air cooled from 1,050° C.	126
	Furnace cooled from 1,050° C.	71
80	Water quenched from 900° C.	133
	Water quenched from 900° C. and aged 2 hours at 500° C.	124
	Water quenched from 900° C. and aged 4 hours at 500° C.	120

Specimens soaked 30 minutes in each case.

tween slow and fast cooling, and this presumably serves to indicate the rate of cooling which is operative. The rate of cooling will depend, of course, upon both the conveyor speed and the temperature gradient at the exit end of the furnace. Reverting to the information on solid iron-copper alloys contained in Table II, it is evident that the forged alloys are stronger and less ductile than the annealed alloys, and it is most likely that this is a cooling rate effect of the type described.

There is little doubt that the superior hardening effect in alloys quickly cooled from temperatures of 900° C. and above is to be connected with the transformation which occurs at 833° C. It has been observed that all quickly cooled alloys are fully magnetic, so there can be no question of full retention of the γ -phase but there is, however, every possibility that the copper which is dissolved in the γ -phase is retained in super-saturated solution in α -iron. This would result in lattice strain, with a consequent hardening effect that would be greater as the amount of copper increased, which is in accordance with the evidence. The effect of subsequent ageing would be two-fold in regard to the hardness: the precipitated copper would tend to increase, and the release of lattice strain in the α -iron to decrease, the hardness. The evidence in Table III indicates that the latter effect is the more important.

It can be said, therefore, that two very important factors determine the properties of iron-copper alloys, i.e., the amount of alloyed copper and the heat treatment, in particular the cooling rate from temperatures above 833° C. such as might be operative in the infiltration cycle itself. Against this background it is now possible properly to consider the particular importance of the skeleton material in regard to the properties of the infiltrated compact.

Properties of Infiltrated Material

INFLUENCE OF TIME OF INFILTRATION

In the case of a skeleton which is prepared from iron powder, diffusion of copper from the molten infiltrant into the iron will take place during the infiltration process. Such diffusion will be time-dependent, and the amount of copper absorbed will thus depend upon, among other things, the period of the infiltration cycle. In view of the known influence of copper on the properties of the iron, this aspect was considered worthy of some investigation, and Table V presents information on this point.

The first result is that given in the latter part of Table IV and, in fact, the compacts referred to above are

TABLE IV.—THE EFFECT OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF SINTERED AND INFILTRATED IRON MATERIAL

Material	Composition	Heat Treatment	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)	Brinell Hardness (10 mm., 500 kg.)
Porosint sintered iron (Density 8.2 g./cc. skeleton for infiltration)	100% Iron	Furnace cooled	17,000	2.0	50
		Air cooled	17,000	2.0	50
Infiltrated iron (80% pore filling, Cu-1% infiltrant)	19% Copper—balance iron	Furnace cooled	39,000	8.4	75
		Conveyor furnace cooled	50,000	4.0	85
		Air cooled	55,500	1.5	92

TABLE V.—EFFECT OF TIME OF INFILTRATION ON MECHANICAL PROPERTIES

Soaking Time at Infiltration Temperature (min.)	Cooling Conditions	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)
10	Furnace cooled	39,000	8.4
30	Furnace cooled	41,000	4.5

Infiltration Temperature: 1,120° C. Atmosphere: Exothermic gas.

identical save for the extended soaking period of 30 minutes in the second case. The furnace cooled condition was chosen in order to show the most critical influence upon properties. It is apparent that the longer soaking period has increased the tensile strength and has brought about a reduction in the elongation. It is reasonable to assume that more copper has diffused into the iron in the latter case, and the trend of the properties is as would be expected from such a condition.

INFLUENCE OF DEGREE OF SINTERING AND COMPOSITION OF THE SKELETON

As emphasized previously, the skeleton forms the framework of the infiltrated body, and it is important to consider the condition prior to infiltration, in so far as it will determine the properties of the final material. In addition, if, as has been shown to be the case, diffusion of copper into the skeleton can influence the properties, then the distance over which diffusion occurs, besides the time period of diffusion, will also determine the final copper level in the iron skeleton. In this context it is necessary to consider the degree of sintering of the iron skeleton, as this will determine the degree of inter-particle welding, and thus the minimum diffusion distance. The particle weld-areas are of the utmost importance in determining the strength of a compact, and the greater the degree of sintering the thicker will be the weld.

A series of compacts has been prepared to examine this aspect, and the detailed results are set out in Table VI. Also in this table are included some results covering parallel tests on skeleton compacts to which 8% of copper had been specifically added. It has been stated previously that the equilibrium copper content of iron at the infiltration temperatures is of this level, and the aim was to help elucidate the importance of copper in the skeleton.

Tensile compacts were prepared in all cases, and three degrees of sintering were applied to the iron materials: in the first case the green compacts were used as skeletons; in the second case compacts were sintered in a conveyor furnace (a different installation from that previously mentioned, and thus liable to give different rates of cooling) at 1,120° C., using cracked ammonia, and at such a speed as to give approximately 20 minutes at temperature; and in the third case, compacts were sintered for 1 hour at 1,300° C. in an atmosphere of hydrogen in a molybdenum furnace. All the skeleton compacts were then infiltrated in the same conveyor furnace, under conditions identical with those of the sintering treatment, i.e., using cracked ammonia and the same belt speed, again giving approximately 20 minutes at 1,120° C.

The iron-copper skeleton compacts were used in the green condition, and also after being sintered in the conveyor furnace under conditions identical with those applied to the iron compacts. The infiltration conditions were likewise identical, since all the skeleton compacts

TABLE VI.—EFFECT OF DEGREE OF SINTERING AND COMPOSITION OF THE SKELETON ON PROPERTIES OF INFILTRATED MATERIAL

Sintering Conditions	Skeleton Properties				Infiltrated Properties			
	100% Iron Skeleton Material							
	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)	Dimensional Change on Sintering (%)	Density (g./cc.)	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)	Dimensional Change on Infiltration (%)	Density (g./cc.)
Unsintered (i.e., green)	—	—	—	6.34	65,000	1.0	+ 1.0	7.63
Conveyor Furnace—1,120° C. (20 minutes)	20,000	3.0	— 0.1	6.33	79,500	2.0	+ 1.2	7.60
1,300° C. (1 hour)	29,000	18.0	— 2.1	6.75	66,500	6.0	+ 1.0	7.65
	92% Iron-8% Copper Skeleton Material							
	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)	Dimensional Change on Sintering (%)	Density (g./cc.)	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)	Dimensional Change on Infiltration (%)	Density (g./cc.)
	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)	Dimensional Change on Sintering (%)	Density (g./cc.)	Ultimate Tensile Strength (lb./sq. in.)	Elongation (%)	Dimensional Change on Infiltration (%)	Density (g./cc.)
Unsintered (i.e., green)	—	—	—	6.48	66,300	1.0	+ 1.4	7.57
Conveyor Furnace—1,120° C. (20 minutes)	46,400	1.0	+ 1.30	6.18	85,000	1.0	— 0.2	7.95

Skeletons: Compacts formed at 25 tons/sq. in. from MH100 iron and electrolytic copper powders.

Infiltrant: Cu-Fe, 90% filling of calculated pore volume.

Dimensional change: — Shrinkage; + Growth.

were treated together. The object of using identical sintering and infiltration conditions in the one conveyor furnace was to ensure that the heat treatment effect was not a variable to the series of tests.

The Degree of Sintering

The variously sintered iron skeletons show a wide range of properties. The green compact has virtually neither strength nor ductility, whilst the influence of the higher sintering temperature has been to develop a reasonably high elongation (18%) without such a proportional increase in strength over the 1,120° C. treatment. Figs. 3 and 4 are photomicrographs of the compacts, sintered at 1,120° C. and 1,300° C., respectively, from which it is apparent that broader particle welds and a degree of pore spheroidisation have developed at the higher temperature.

The infiltrated compacts show a trend of increased elongation with degree of sintering, whilst the maximum strength is observed to lie with the 1,120° C. sintered compacts. Figs. 5, 6, and 7 are photomicrographs of these infiltrated compacts and, apart from a general smoothing effect upon the pore surfaces by the molten infiltrant, it appears that in the case of Figs. 6 and 7 the

areas of infiltrant faithfully reflect the pore shape and disposition evident in the parent skeletons, i.e., Figs. 3 and 4. The 1,300° C. sintered material exhibits areas of infiltrant which are less continuous and more isolated than in the other two instances, and the broader particle welding compared with that of the other compacts is seen in the high degree of continuity of the ferrous skeleton. Some empty pores are evident in all compacts, and these are evidently blind pores which could not possibly be infiltrated.

It is considered that the correlation of ductility with degree of sintering reflects the diffusion of less copper, because of the greater distance, into the wider particle junctions of the compacts sintered to the highest degree. This results in a more ductile skeleton within the infiltrated compact. The tensile strength by the same process would normally decrease as the ductility increases and, indeed, the 1,300° C. compacts are not so strong as the 1,120° C. material. However, it is also true that the strength must depend upon the cross-section of the ferrous metal itself, i.e., the degree of inter-particle welding in the skeleton, and the unsintered skeleton will have developed the least cross section of all. Consequently, the lower strength of these compacts may be

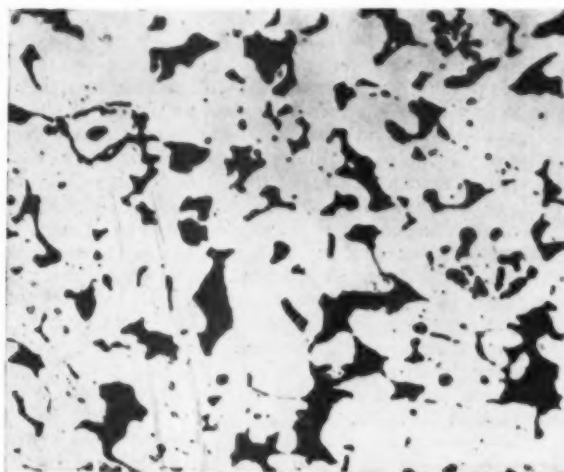


Fig. 3.—Iron skeleton sintered at 1,120° C. Unetched. $\times 400$.

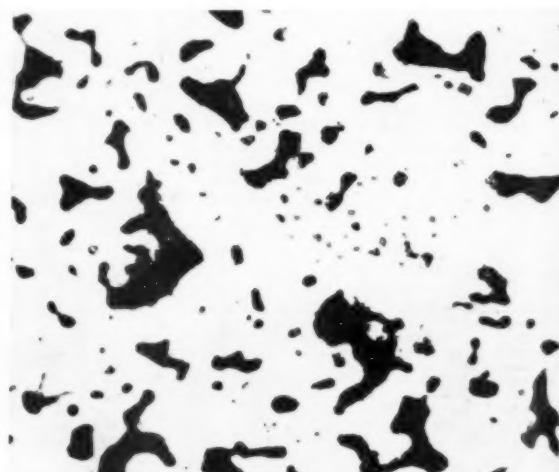


Fig. 4.—Iron skeleton sintered at 1,300° C. Unetched. $\times 400$.

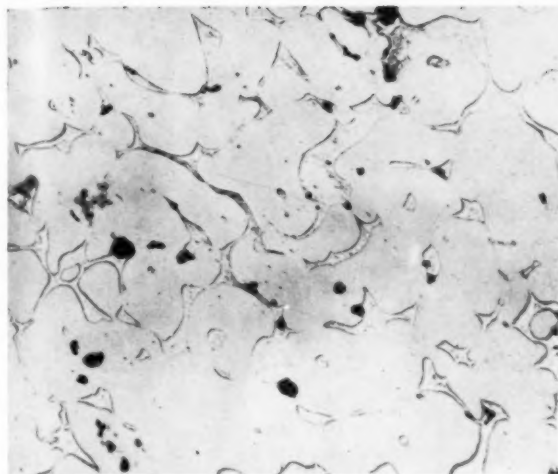


Fig. 5.—Infiltrated green iron skeleton. Unetched. $\times 400$.

due to the emphasis of this factor. It has, incidentally, been observed by the author that skeletons fabricated from finer iron powders than those considered here show rather less ductility and greater strength than normal, and this is thought to reflect a greater copper diffusion effect, because of the shorter distances involved. The presence of more copper would, in addition, make the material more susceptible to heat treatment effects.

Skeleton Composition

The addition of 8% of copper to the iron skeleton material has a marked effect on the skeleton properties. For the compacts sintered in the conveyor furnace the strength is more than doubled and the ductility is impaired by comparison with the straight iron material. The green and sintered compacts after infiltration both show very low elongation, but the latter has the greater strength, and it is likely that this is due in part to a greater development of inter-particle weld area. The strengths and ductilities of the iron-copper green and sintered skeletons after infiltration compare fairly well with the corresponding compacts based on iron skeletons, and this probably indicates approximately equal progress of alloying.

Figs. 8 and 9 are photomicrographs of the sintered skeleton before and after infiltration, respectively, and it is interesting to note that full alloying of the iron and copper in the skeleton has not quite been achieved during the pre-sintering operation. The infiltrated material is characterised by a high degree of rounding of the contours of the pore surfaces. The lack of full alloying in the sintered iron-copper compact (Fig. 8) after 20 minutes at $1,120^{\circ}\text{C}$. is significant, in so far as it indicates that, under the conditions described, degrees of diffusion exist, as the evidence would seem to suggest.

Significance of the Dimensional Changes

The basic tendency for every porous compact is to shrink in order that the free surface may be reduced and, indeed, the iron skeletons have shrunk more as the degree of sintering has increased (Table VI). In the case of iron-copper compacts, however, there is a growth upon sintering, and this is recorded as 1.3% linear.

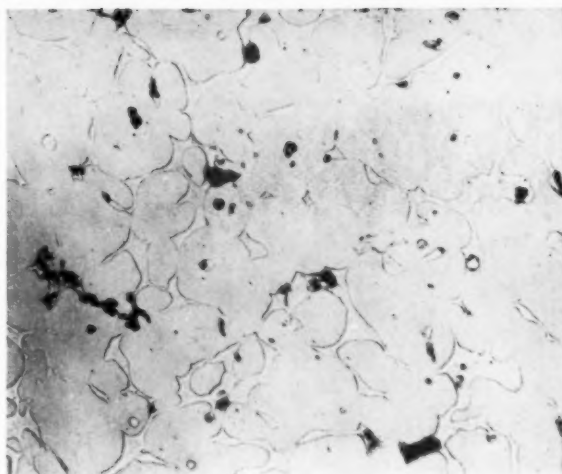


Fig. 6.—Infiltrated iron skeleton which had been sintered at $1,120^{\circ}\text{C}$. Unetched. $\times 400$.

Study of the growth phenomenon has indicated that it is to be connected with the presence in the compact of an alloying element which at some stage of the sintering process is in a relatively mobile condition, and perhaps even fully molten. The growth occurs in the early stages of sintering, whilst a mobile phase is present, and is superimposed upon the shrinkage effect which is always operative. It is considered that the growth arises essentially from an unbalanced movement of metal in the compact, and that in the case of iron-copper material it is due to the movement of copper. In the unsintered compact, discrete particles of iron and copper lie adjacent to one another: as the melting point of the latter is approached, the copper rapidly absorbs iron to its equilibrium level from surrounding particles and, upon melting, tends to spread itself over the iron surfaces by surface tension forces. The copper of the molten copper-iron alloy is gradually absorbed into the iron by a process of solid diffusion, whilst the iron precipitates

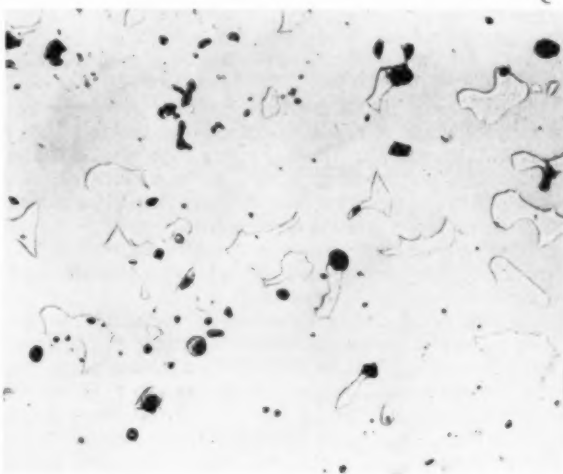


Fig. 7.—Infiltrated iron skeleton which had been sintered at $1,300^{\circ}\text{C}$. Unetched. $\times 400$.

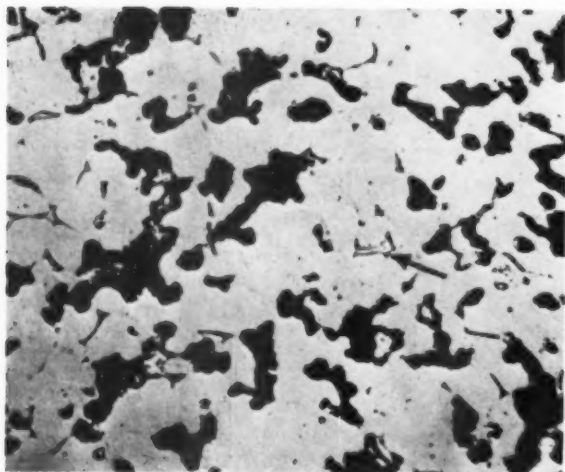


Fig. 8.—Iron-8% copper skeleton sintered 20 minutes at 1,120° C. (Arrow indicates free copper). Unetched. $\times 400$.

upon the internal skeleton surfaces. There is a consequent transfer of copper from spaces between the iron particles into the iron itself, and since the density of the resultant iron-copper alloy approximates to the density of pure iron, an increase in the volume of the iron must arise during the process, i.e., it grows.

Such is the origin of the growth, and it will be appreciated that it depends essentially upon the alloying which takes place in the iron. For instance, it is known that additions to iron-copper compacts which reduce the mutual solubility of iron and copper also reduce the sintered growth. In the infiltration process precisely the same considerations apply, and in Table VI it will be noted that all the skeletons which contain pure iron, including the green iron-copper material, show a growth upon infiltration which is an indication of alloying taking place. The sintered iron-copper skeleton, on the other hand, shrunk slightly during infiltration, and the amount of shrinkage agrees with that to be observed if the compact had been simply re-sintered, as distinct from infiltrated, during the second heating cycle. The evidence points to little further alloying taking place as, indeed, should be the case.

Consideration of Results

From a consideration of the mechanical properties, dimensional changes, and microscopic examination, it is possible to explain the characteristics of infiltrated material entirely in terms of alloying and heat-treatment effects in the iron-copper system, and there is no evidence as to structural changes other than those which occur in this way. The smoothing effect of the molten infiltrant upon the pore surfaces is believed to be a surface one only.

Bearing in mind that the aim of the infiltration process is to prepare compacts which are stronger and, particularly, more ductile than their porous counterparts, it is of interest to consider the best means of achieving this object. A skeleton consisting of an iron compact pre-sintered to a high degree from a relatively coarse powder, and infiltrated for the shortest possible time, will ensure least alloyed copper in the iron, and hence most ductility, although not necessarily the greatest tensile strength. The slowest rates of cooling from the infiltration tem-

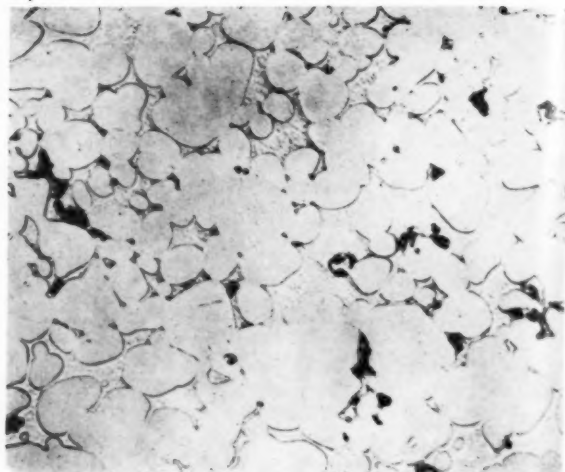


Fig. 9.—Infiltrated iron-8% copper skeleton which had been sintered at 1,120° C. Unetched. $\times 400$.

perature are desirable, but in normal conveyor furnace practice this poses a dilemma, since a high belt speed results in shorter soaking periods but higher rates of cooling, and vice-versa. A compromise is, therefore, necessary, which must depend upon the individual properties required.

It is interesting to note that in order to attain a good combination of strength and ductility, a state of non-equilibrium between iron and copper must be deliberately achieved.

Acknowledgments

The author is indebted to the directors of Bound Brook Bearings, Ltd., for permission to publish this paper.

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Samuel Fox Developments

By the end of 1957, the two largest electric furnaces for steel melting in Britain will be housed side by side in the Stocksbridge Works of Samuel Fox & Co., Ltd., associated with The United Steel Cos., Ltd. The first furnace—now tapping 70 tons—was installed last November and has proved to be an outstanding success. The new furnace, which will be of similar capacity, forms the central feature of a £2,845,000 development scheme.

It will result in a substantial addition to the tonnage of special and alloy steels available each year for use by some of our most important export industries—motor vehicles, civil aircraft, steam generation plant and chemical plant. To process this extra quantity of steel, Samuel Fox, who are one of Britain's largest producers of alloy and stainless steels, plan simultaneously to modernise their billet rolling mill. This will be accomplished with the latest mechanised aids. When completed, the modernised mill will have a capacity of some 8,000 ingot tons of steel a week—one third more than at present. Present-day imports of special steels for consuming industries should be considerably reduced after the new scheme has come into operation.

Continuous Medium Strip Mill Project

Site Work in Progress at Steel, Peech & Tozer

PRELIMINARY site work is now in progress on a £3.6 million continuous medium strip mill project at the Rotherham works of Steel, Peech & Tozer, a branch of The United Steel Cos., Ltd. Known as the Brinsworth strip mill, the plant will be located on the opposite side of the Sheffield Road from the company's main Templeborough works. It will comprise a main building of low-high roof construction, approximately 800 ft. long by 300 ft. wide, arranged in four bays—motor room and mill grinding bay, main mill bay, slab storage and conditioning bay, and coil storage and despatch bay. A separate building for pickling plant will be erected later, while long-term plans envisage the installation of cold rolling mills and annealing plant on the same site.

The mill, which is intended to bridge the gap between the output of the narrow and wide strip mills at present operating in this country, is being supplied by the Loewy Engineering Co. Ltd. It is being designed to produce strip from 4 in. to 18 in. wide with a maximum thickness of $\frac{1}{4}$ in. down to 0.042 in. minimum in deep drawing, mild, medium carbon, razor and stainless qualities.

Description of the Plant

Slabs for reduction in the mill will come from the Templeborough works, where existing plant is being modified for this purpose. After reheating in two oil-fired furnaces, each of 60 tons per hour capacity, the slabs will be transferred to the first section of the mill—a horizontal edging and scalebreaking stand, driven by a 350 h.p. A.C. motor with flywheels. The horizontal edger will be equipped with manipulators on the front and back sides to turn slabs to the vertical for edging, and to position them in the correct pass line.

Following this will be the roughing train, comprising four two-high roughing stands, having 21 in. diameter rolls of 24 in. barrel. Stands in the roughing train will be spaced out so that the stock is free between stands, with the exception of stands Nos. 3 and 4, which will be close-spaced. No. 1 stand will be driven by a 700 h.p. A.C. motor with flywheel, Nos. 2 and 3 by 1,200 h.p. A.C. synchronous motors, and No. 4 stand by a 1,200 h.p. D.C. motor.

After leaving the roughing mill, the stock will travel along a 190 ft. long delay table before encountering a vertical edger—one of three such edgers in the complete installation. A flying shear will be located at the end of the delay table for end trimming and in order to deal with "cobble".

In the finishing train of the strip mill, there will be six four-high stands, each having 14 in. diameter work rolls and 23 in. diameter back-up rolls. All rolls in this train will be of 23 in. barrel. Stand No. 1 will be driven by a 1,200 h.p. D.C. motor, Nos 2, 3, 4 and 5 by 1,750 h.p. D.C. motors, and No. 6 by a 1,200 h.p. D.C. motor. Strip leaving the finishing mill will be formed into coils on either of two horizontal mandrel type down-coilers.

The mill will be equipped throughout with electric screw-down gear, and four high-pressure water descaling stations will be situated at various points in the train. Fabric bearings are being adopted on the roughing train,

with roller bearings on the finishing train. All the main electrical equipment for the mill, including the motor drives, is being supplied by the English Electric Co. Ltd. All auxiliary D.C. motors, up to and including 150 h.p., are being supplied by Metropolitan-Vickers Electrical Co., Ltd.

Initially, the Brinsworth strip mill will produce 3,000 tons of strip per week, increasing gradually to 6,000 tons per week, which is the designed capacity of the mill.

E.S.C. Celebrate Steel Castings Centenary

(continued from page 225)

One of these recently despatched from the works, was the largest railway casting of its kind ever made outside the United States. It was the first of a series of one-piece cast steel three axle driving truck beds for New South Wales Government Railways' 3,820 h.p. 0-6 + 6-0 electric locomotives, which Metropolitan Vickers-Beyer Peacock, Ltd., are building at their Stockton Works, and for whom English Steel Castings Corporation are sub-contractors.

Measuring almost 25 ft. in length by 8 ft. in width, and weighing approximately $7\frac{1}{2}$ tons, the truck beds, which are of heat treated steel equivalent to A.R. specification M.201-52 Grade "A", are designed to carry three 1,500 volt force ventilated motors mounted on each axle.

The locomotive superstructure is carried on a pair of truck beds, joined by means of a special articulation coupling which permits spring controlled lateral movement, whilst the locomotive is traversing a reverse curve. To compensate for the shortening of truck centres on curves, one of the pair is allowed one inch of longitudinal movement at the centre of the casting. The rail load per axle is 18 English tons, whilst a notable design feature is the mounting of the draw and buffing gear on the truck headstocks.

The locomotives, forty in all, which are for lifter goods or passenger traffic, will be used on lines running over the Blue Mountains, where the track rises from sea level at Sydney to 3,500 ft. with ruling gradients of 1 in 33. Their maximum operating speed is 70 m.p.h.

Philips Offer Heating Facilities

As an additional service to manufacturers, Philips Electrical, Ltd., announce that they are now able to undertake limited quantities of induction soldering, brazing, etc. The production economies which can be achieved by using induction heating techniques are already well known, but it is frequently impossible to take advantage of them—particularly on a small output—because of the high initial cost of equipment. For this reason, Philips are making available the production capacity of the H.F. generators installed for demonstration and research in their Industrial Applications Centre at Brixton. Further details are obtainable from the Electronic Heating Department of Philips Electrical, Ltd., (Industrial Products Division) Century House, Shaftesbury Avenue, London W.C.2.

The Isothermal Transformation Characteristics of Carburized 2% Nickel-Molybdenum Steel

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The Mond Nickel Co., Ltd., Development and Research Dept.

Isothermal-transformation diagrams of steels representing the core and four positions in the case of a carburized 2% nickel-molybdenum steel have been determined. Increase in carbon content (i) delays the start of transformation, (ii) hastens its completion in the pearlite range, but (iii) delays completion in the bainite range. Variation in austenitizing temperature, in the range 770°–915° C., produces no change in the isothermal-transformation diagrams of the core and case (at 0.84% carbon). The mechanical properties of steels of typical core composition are included.

THE classic and pioneer work of Davenport and Bain¹ on the isothermal-transformation behaviour of steels has been followed by numerous investigations, employing various techniques. Several atlases of isothermal-transformation diagrams are now available, covering British, American and German types of steel.^{2,3,4,5,6} These data apply mainly to direct-hardening steels, and there is little published information on carburized steels. Isothermal-transformation diagrams for the latter would, however, be at least as valuable as for the former, particularly for yielding information on the treatments which should be employed for martempering and isothermal annealing. For such purposes the need is for a series of diagrams representing both the variation in carbon content from the core through the carburized case, and the effect of various heat-treatments used in practice.

This note presents diagrams portraying the isothermal-transformation characteristics of a carburized 2% nickel-molybdenum steel (B.S. En 34). The steels studied cover a range of carbon contents corresponding to the core and four positions in the case of the carburized material. The majority of the results correspond to the hardening stage of the double-quenching treatment (final oil-quenching from 770° C.), which is often used for carburized components, but for the core and the 0.84% carbon steels, diagrams representative of single-quenching treatments, (a) from 840° C., and (b) from the carburizing temperature (915° C.), are also included.

The 2% nickel-molybdenum steel was selected for this study because of its wide application in industry. Carburized steels of this type can be heat-treated in a variety of ways to produce consistently good mechanical properties in the core material (see typical values given in Table I). Furthermore, the tendency for grain-boundary carbide formation in the case is reduced by the presence of nickel.⁹

Experimental Procedure and Results

Five steels, having the compositions listed in Table II, were made as 100-lb. melts in a basic-lined high-frequency induction furnace. The steels were hot-forged and -rolled, and subsequently cold-drawn to 9 s.w.g. wire and 0.03-in. thick tape.

Isothermal transformation in all the steels except the 0.84% carbon type was followed by the microscopic

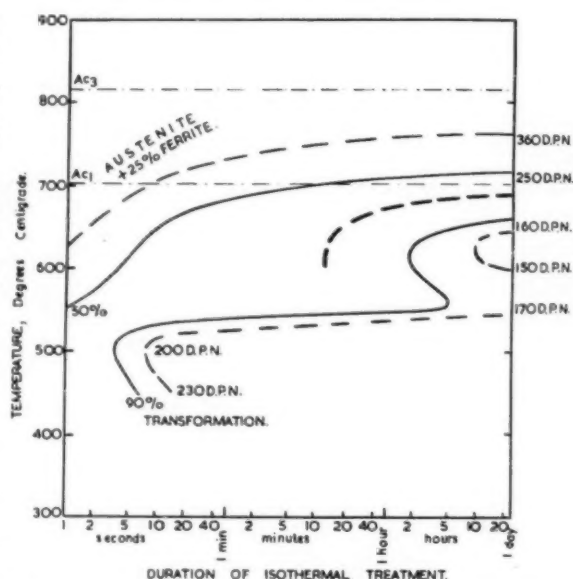


Fig. 1.—0.16% C, 2% Ni-Mo steel, refined from 865° C. and austenitized 30 minutes at 770° C.

method,¹ using 0.03-in. thick tape samples. For the 0.84% carbon steel the dilatometric method¹⁰ was employed, on specimens machined from the 9 s.w.g. wire: the extent of reaction after apparent completion of transformation, or after a time of 24 hours (whichever was the shorter), was determined microscopically. M_s temperatures were determined by the Greninger and Troiano technique,¹¹ and the critical temperatures dilatometrically, on heating at a rate of 100° C./hour. Hardness values were measured on specimens quenched into water after completion of isothermal transformation, or after the 24 hour treatment.

The isothermal transformation diagrams are presented in Figs. 1–9. Figs. 1–5 are for an austenitizing treatment at 770° C., and correspond to the hardening stage of the double-quenching treatment; prior to austenitizing at 770° C. all the specimens were given a refining treatment from 865° C. Figs. 6–9 correspond to single-quenching treatments without previous refining. Thus, Figs. 6 and

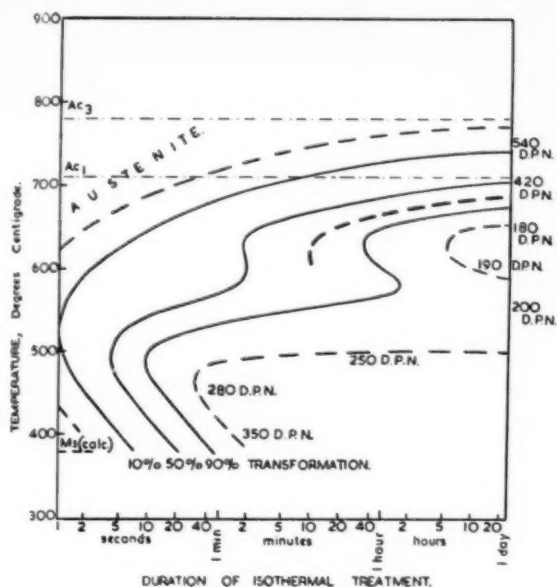


Fig. 2.—0.29% C, 2% Ni-Mo steel, refined from 865° C. and austenitized 30 minutes at 770° C.

7 are for the core and one position in the case (0.84% carbon) after austenitizing at 840° C., and Figs. 8 and 9 relate to the same steels quenched from the carburizing temperature.

Discussion of Results

It will be observed from Figs. 1-5 that the progressive increase in carbon content from the core through the

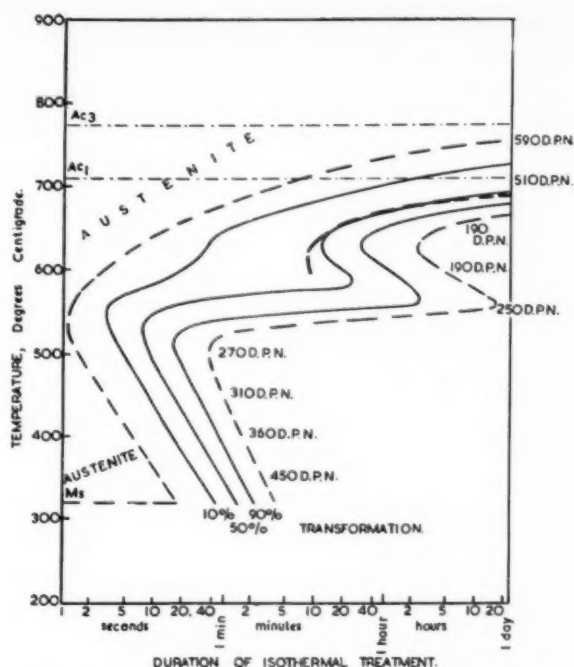


Fig. 3.—0.37% C, 2% Ni-Mo steel, refined from 865° C. and austenitized 30 minutes at 770° C.

case of a carburized 2% nickel-molybdenum steel results in:

- (a) greater stability of the under-cooled austenite and, therefore, longer incubation periods in both the pearlite and bainite ranges;

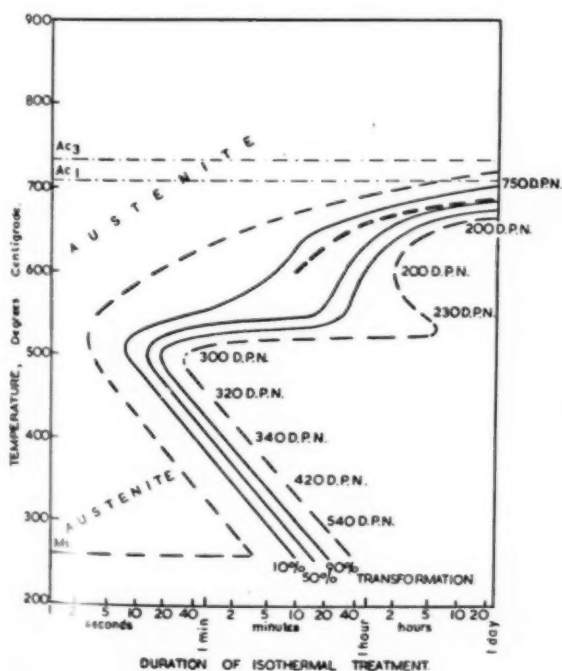


Fig. 4.—0.55% C, 2% Ni-Mo steel, refined from 865° C. and austenitized 30 minutes at 770° C.

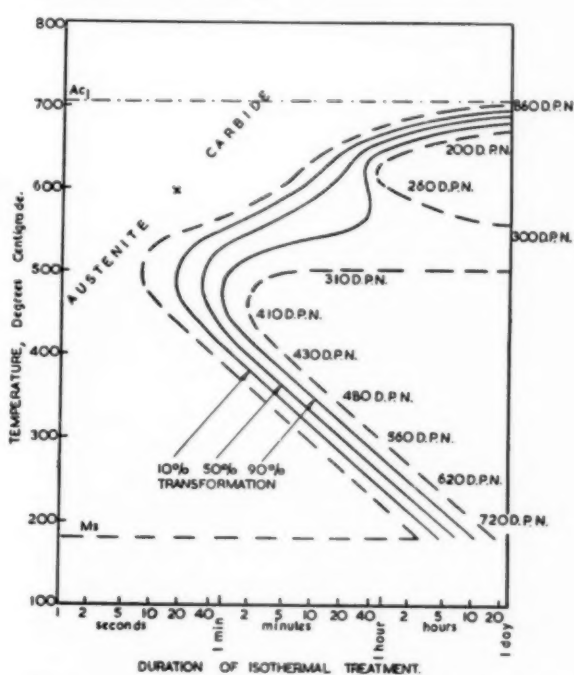


Fig. 5.—0.84% C, 2% Ni-Mo steel, refined from 865° C. and austenitized 30 minutes at 770° C.

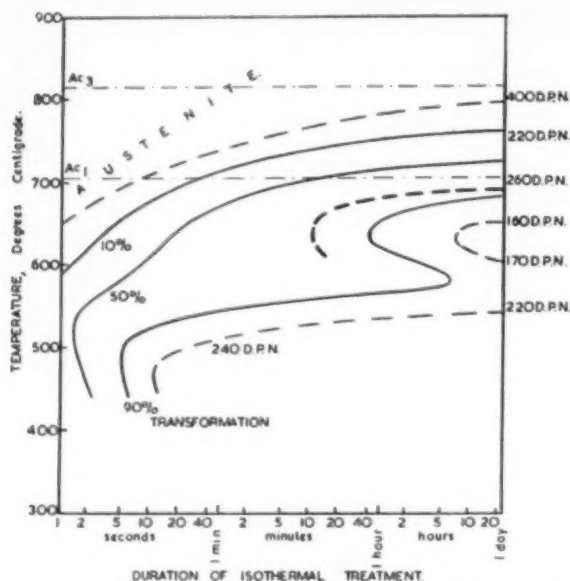


Fig. 6.—0.16% C, 2% Ni-Mo steel, austenitized 30 minutes at 840° C.

- (b) earlier completion of isothermal reaction in the pearlite range; and
(c) later completion of isothermal reaction in the bainite range.

The isothermal transformation diagrams for the steel of core composition austenitized at different temperatures (Figs. 1, 6 and 8) are very similar, as are those for the 0.84% carbon steel variously treated (Figs. 5, 7 and 9).

From the practical aspect, the diagrams show that in order to obtain adequate case hardness on martempering, the controlling factor is the cooling rate required to avoid transformation during cooling to the salt-bath temperatures usually employed. If this critical rate is exceeded

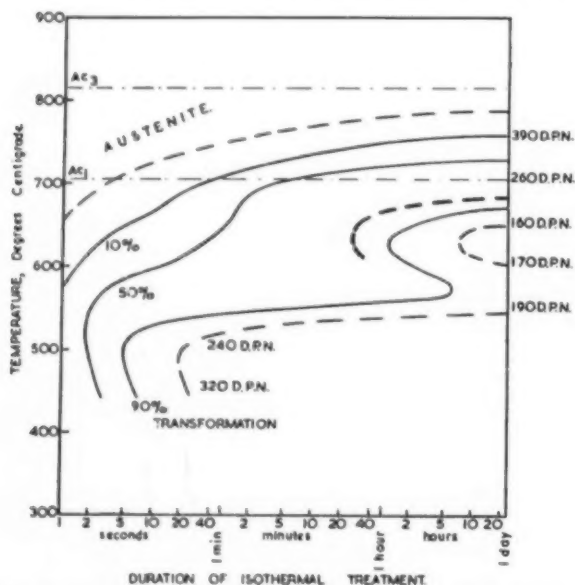


Fig. 8.—0.16% C, 2% Ni-Mo steel, austenitized 30 minutes at 915° C.

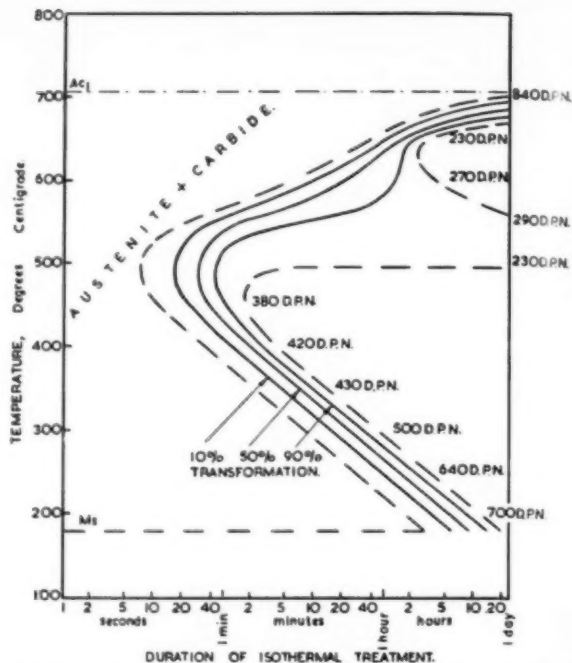


Fig. 7.—0.84% C, 2% Ni-Mo steel, austenitized 30 minutes at 840° C.

there is ample time for temperature equalization in the salt bath without transformation to bainite. Furthermore, the fact that in both the core and 0.84% carbon steels variation in austenitizing temperature produces little change in the transformation characteristics, explains why quenching from markedly different

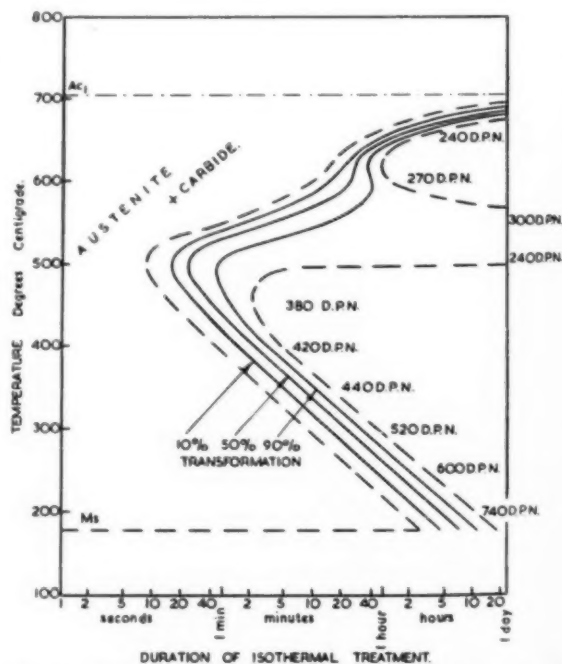


Fig. 9.—0.84% C, 2% Ni-Mo steel, austenitized 30 minutes at 915° C.

TABLE I.—TYPICAL MECHANICAL PROPERTIES FOR 2% NICKEL-MOLYBDENUM (B.S. En 34) STEEL

Composition					Diameter in.	Heat Treatment	Mechanical Properties			
C %	Mn %	Ni %	Cr %	Mo %			0.5% P.S. tons/sq. in.	U.T.S. tons/sq. in.	Elong. %	Ivot ft.-lb.
0.13	0.40	1.78	0.23	0.27	1	O.Q. 865°C. + O.Q. 770°C.	31.8	51.0	27	45
					1 1/2	O.Q. 870°C. + O.Q. 780°C.	31.8	50.4	31	52
					1 1/2	O.Q. 820°C. + O.Q. 820°C.	37.0	68.6	20	40
0.15	0.55	1.83	0.09	0.27	1	10 hrs. 900/910°C. O.Q.	—	53.1	22	50
					1 1/2	O.Q. 900/910°C. +	—	59.2	24	55
					1 1/2	O.Q. 770/780°C.	—	54.3	26	57
0.19	0.50	1.74	0.3	0.25	1	O.Q. 850°C. +	40.0	55.4	20	51
					2	O.Q. 760°C.	34.8	47.6	24	63
					3		30.8	46.0	25.5	80
					4		25.0	45.1	22.5	66

* This investigation. † Hodgson. ‡ Mond Nickel Co., Ltd., Publication No. 468B.

TABLE II.—COMPOSITIONS OF STEELS AND AUSTENITE GRAIN SIZES

Mark	Composition										Austenitizing Temperature °C.	As- Quenched Grain Size A.S.T.M. No.
	C %	Si %	Mn %	S %	P %	Ni %	Cr %	Mo %	Cu %			
PVA	0.16	0.16	0.44	0.029	0.011	1.90	0.09	0.28	0.22		770 840 915	10 7-10 7-9
PVB	0.29	0.25	0.47	0.022	0.015	1.90	0.07	0.28	0.12		770	10-11
PVC	0.37	0.37	0.50	0.019	0.015	1.75	0.05	0.28	0.12		770	10
PVD	0.55	0.16	0.51	0.029	0.014	1.85	0.04	0.24	0.12		770	9-10
PVE	0.84	0.23	0.54	0.021	0.016	1.90	0.04	0.26	0.18		770 840 915	9-11 9-10 8-10

austenitizing temperatures produces similar properties in the core and case of carburized components of this steel. The diagrams presented show also that the optimum temperature for isothermal softening is about 625° C., and is independent of austenitizing temperature.

Acknowledgment

The authors wish to thank The Mond Nickel Co., Ltd. for permission to publish this note.

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Brass Tube Annealing Electric Roller Hearth Furnace Installation

FOLLOWING their policy of re-equipment and expansion, Yorkshire Copper Works, Ltd., of Leeds, have recently put into production a new electrically heated roller hearth furnace for annealing brass tubes. The furnace was designed and installed by G.W.B. Furnaces, Ltd., of Dudley, and is designed to heat treat tubes up to 6 in. diameter, in lengths up to 28 ft. An output of 30 cwt. of tubes per hour at 650° C. may be obtained with an electrical rating of 225 kW., arranged in three independent automatically controlled zones, although the average output is normally 25 cwt./hr. with a charge of 3 in. o.d. x 16 s.w.g. 70/30 brass tube. Zones 1 and 2, where the initial heating up of the charge takes place, are rated at 85 kW., and zone 3 at 55 kW. The unit is fed from the 3-phase mains supply, distributed equally across the phases, and heating elements in each zone are fed through tapped transformers to give reduced ratings when working in the lower temperature ranges, and when treating relatively light charges. The transformers supplying zones 1 and 2 are fitted with taps giving 75, 65, 55 and 45 kW., while the transformer supplying zone 3 is fitted with taps at 45, 35, 25 and 15 kW.

The heating chamber is 20 ft. long x 3 ft. 9 in. usable

width and is suitable for accommodating charges up to 6 in. in height. Zones 1 and 2 are each 5 ft. long, while zone 3 is 10 ft. long. A water-jacketed cooling



Electrically heated roller-hearth tube annealing furnaces. The capacities of the left hand and right hand units are 20 cwt./hr. and 30 cwt./hr. respectively.

chamber, 23 ft. 6 in. long, is fitted at the exit end of the heating portion of the furnace, so that a gradual cooling of the charge is achieved, giving the desired mechanical properties to the tubes. In order to obtain a degree of heat balance from one end of the unit to the other, and to cut down excessive end heat losses, an entrance vestibule 1 ft. 6 in. long is provided. These balanced conditions would also tend to reduce protective atmosphere losses, should this form of charge protection be utilised.

Heating elements take the form of heavy nickel-chromium strip fitted in the roof and hearth of the heating chamber. Those in the roof are carried on nickel-chromium hooks, while the hearth elements are supported on specially moulded refractories.

All rollers throughout the installation, including those in the 30 ft. long loading table, are power-driven. Generally, all rollers are at a pitch of 1 ft., except in the heating chamber itself, and otherwise where subjected to heat, in which case they are 6 in. apart, in order to give maximum support to the brass tubes when at elevated temperatures. The rollers in the hot portion of the furnace are of a heat-resisting alloy, while elsewhere they are of normal mild steel. All rollers are flanged in order to locate the charge, and by a special design arrangement they may be extracted, when necessary, through the side of the furnace. Another design feature which considerably eases internal maintenance and enables any jams to be speedily released is the lift-off roof of the

heating chamber, which is removable in sections. When in position, the roof rests in a gas-tight sealing trough running round the bottom half of the furnace body. Special attention has been paid to the question of suitable bearings for the rollers, and it has been found that the self-aligning graphite type is most satisfactory. To cater for differences in the charge characteristics, the roller speed can be adjusted by means of a Carter infinitely variable hydraulic gear box; a speed indicator is included.

Temperature control is most critical in this process, and three Electroflo electronic indicating controllers are provided, one for each zone, while a 3-point recording instrument is also fitted in the control panel so that a positive visible check on thermal conditions throughout the process cycle may be obtained. The operating temperature of the furnace varies between 325° C. and 650° C., depending principally upon the type of charge and the degree of anneal required by the customer.

This particular furnace is a larger version of a similar unit supplied in 1950 to Yorkshire Copper Works, Ltd., the earlier furnace having a maximum output of 1 ton per hour with a rating of 170 kW., and a usable width of 2 ft. 6 in. This smaller unit has a power consumption of 102 kWh./ton of tubes treated at 550° C., and while no figures are at present obtainable for the more recent furnace, it is reasonable to assume that an equivalent performance is achieved.

Society of Chemical Industry Corrosion Group Awards for Essays on Corrosion Science

THE Education Panel of the Corrosion Group, with the approval of the Council of the Society of Chemical Industry, announces the establishment of a competition designed to encourage those who are still in the early stages of their career to take an interest in corrosion science and to express their ideas in writing. Details are as follows:—

(1) With the support of industrialists interested in the application of corrosion science in industry, it is proposed to offer a prize of the value of 25 guineas to be awarded annually for an essay or paper on any aspect of corrosion of metals and its prevention.

(2) Essays are invited from persons aged not more than 27 years on the closing date. A length of about 3,000 words is suggested; but reasonable latitude may be exercised.

(3) Judgment of the entries by a specially appointed panel will be based on arrangement of material, technical and literary excellence, and the evidence shown of the candidate's critical faculty and originality of thought. It is not necessary that the results of original research should be incorporated; entries may include, for example, surveys of knowledge in a particular field, discussion of practical problems, and suggestions for future developments in research, in application of knowledge, or in organisation of corrosion-preventive measures. The prize may be withheld, if, in the opinion of the judges, no entry of sufficient merit has been received.

(4) Any candidate may subsequently be invited to deliver his or her contribution as a lecture.

(5) Publication of any entry will rest with the Society of Chemical Industry, subject to the regulations of the Society.

(6) Entries should preferably be typed (double spaced), and must be on one side of the paper only with adequate margins. The candidate's name must not appear on the script. The entry must be enclosed in a sealed envelope bearing a pen-name. A second sealed envelope also bearing the pen-name and enclosing a statement of the full name, address and date of birth of the author must accompany the entry. The second envelope will be opened in the presence of the Committee of the Education Panel when the judges make their reports. Illustrations (diagrams and/or photographs) may be included with the entry, but must not provide means of identifying the author.

(7) The closing date for receipt of entries is 31st March, 1956. They should be addressed to: Corrosion Group Essay Competition, c/o Society of Chemical Industry, 56, Victoria Street, London, S.W.1. Further particulars of the competition, including fuller details of the form in which the entries are to be submitted may also be obtained from this address.

Export Contract for Italy

THE Loewy Engineering Co., Ltd., has secured against international competition an order from the important steelworks of Ilva for a continuous medium strip mill worth more than £500,000, and due to be delivered by the end of 1956. The plant is similar to, but somewhat smaller in size than, the continuous strip mill which, as recently announced, is being built by Loewy for Steel, Peech & Tozer, a Branch of The United Steel Cos., Ltd.

THE address of Refractory Mouldings and Castings, Ltd., has been changed to Pleasant Place, Kegworth, Leics.

The Heat Resistance and Applications of Hot Dip Aluminized Steel*

By M. L. Hughes, Ph.D., M.Sc., F.R.I.C., F.I.M.
and D. F. G. Thomas, B.Sc., A.I.M.

South Wales Laboratories, British Iron and Steel Research Association

Scaling tests on steel panels hot dip aluminized by the B.I.S.R.A. process show that the scaling resistance obtained is very good, and somewhat better than that with aluminium-silicon coatings. For comparison, results of tests on sprayed coatings and on coatings produced by the Sendzimir process are included. Tests on the influence of sulphur dioxide in the atmosphere show that there is little effect below 800° C. The applications of hot dip aluminized steel for heat resistance are reviewed, and information is included from other sources on the behaviour of aluminized steel prepared by other hot dip processes.

ALUMINIUM coatings have been used for some years to provide a heat resistant surface for carburizing boxes, annealing covers and similar articles. The calorizing process, which produces an alloy coating by a cementation method, is used for comparatively small articles; for larger articles a sprayed aluminium coating is applied which is heat treated to convert it to alloy.¹ The spraying method has been used to produce a cheap substitute for the expensive alloy steel inner covers used in sheet and coil annealing.

The hot dip aluminizing process has the advantage that a coating of heat resistant aluminium or aluminium-silicon alloy can be applied to sheet, strip or wire, which materials cannot conveniently be coated by spraying or calorizing. Sheet or wire may be given an aluminium-silicon coating thin enough to permit reasonable fabrication after coating. Rigid articles, for which adhesion is less important, may be given much thicker coatings by hot dipping in commercial quality aluminium without the addition of silicon.

The British Iron & Steel Research Association developed a fluxless process for continuously hot dip aluminizing steel wire or strip. In this system the cleaned steel is coated with a thin film of copper or glycerol before entering the aluminizing bath. This film prevents oxidation of the steel, and the glycerol process has the additional advantage that the glycerol burns slowly at the point of entry of the steel into the bath, so producing a reducing atmosphere and, consequently, a cleaner aluminium surface at the entry point.

Some information was already available from American sources on the scaling resistance of hot dip aluminized steel, but it was scanty and referred to material prepared by different processes, e.g., Aldip, using a salt bath. It was considered necessary to establish the heat resisting properties of the B.I.S.R.A. aluminized material because of the different process employed, and because the coatings were in general thinner than those of other processes and sometimes contained silicon, which was added to reduce the iron-aluminium alloy formation, and so improve the formability of the sheet. An investigation has therefore been made of the behaviour of B.I.S.R.A. coated panels heated in a muffle furnace for 2,000 hours at temperatures of 500° C. to 800° C. Similar samples have been treated at temperatures of 600° C., 700° C.,

and 800° C., for 490 hours in a rapid current of air containing some sulphur dioxide. In most of these experiments the specimens were cyclically heated and cooled so as to give about 70 hours at test temperature and 2 hours at room temperature. Panels of plain steel have been included for comparison, but these were rapidly destroyed at the higher temperatures. Sprayed coatings of aluminium, aluminium-silicon and aluminium-cadmium alloys, kindly supplied by Messrs. Metallisation, Ltd., have also been tested under the same heating conditions.

The procedure and results of these heat resistance tests are described in the first part of this paper.

In the second part of the paper some results are given of scaling resistance tests carried out by other workers using aluminized steel prepared by the Aldip process, which also emphasise the excellent scaling resistance properties of aluminized steel in sulphurous atmospheres. Some existing and potential uses are discussed.

Scaling Tests on B.I.S.R.A. Hot Dip Aluminized Steel

Scaling tests were carried out in a muffle furnace using test panels of approximately 2 in. × 3 in., and of 14 gauge to 18 gauge material. In these tests the air circulation was limited to that caused by the furnace door being ajar. This was found to be sufficient to cause heavy scaling of plain steel panels.

Tests were also carried out to determine the effect of a stream of air containing a small percentage of sulphur dioxide on the scaling. These tests were carried out in a vertical tube furnace through which a pre-heated stream of air containing 0.1% by volume of sulphur dioxide was blown (see Fig. 1).

Muffle Furnace Tests

Early experiments carried out at temperatures between 500° C. and 700° C. showed that there was insufficient scaling in a 2,000 hour heating time and, consequently, a range of 600° C. to 800° C. was later employed. It was also soon apparent that the behaviour with cyclic heating and cooling, 70 hours and 2 hours, respectively, was a more rigorous test, and this form of heating was then generally adopted.

In the lower temperature experiments it was observed that the lustre of aluminium-silicon coatings was maintained on heating up to between 500° C. and 600° C.,

* Report No. MW/C/21/55 of the Coatings Committee, Mechanical Working Division, of the British Iron and Steel Research Association.

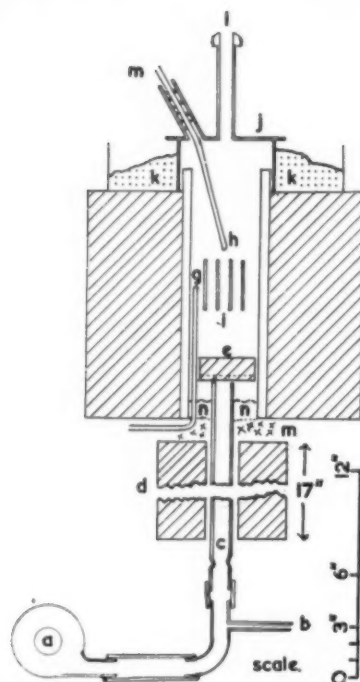


Fig. 1.—Apparatus for examining the influence of moving air and the presence of sulphur dioxide on scaling behaviour.

depending on the coating thickness. This behaviour is due to the silicon slowing up the formation of iron-aluminium alloy, which, in the absence of silicon, quickly forms at this temperature and produces a dark matt surface.

It was found that samples with cut edges gave erratic results, particularly at higher temperatures, and that the weight increase per unit area was affected by the edge scaling by an amount depending on the specimen thickness. Scaling tests at 700° C. using samples with cut edges were carried out by Sully and others,² using B.I.S.R.A. specimens, and these results are compared with those obtained in our tests in Table I. Sully's results are for 1,000 hours heating time only; the specimens were smaller and he collected broken-off oxide, so that his cut-edge effect would be proportionately greater and would largely account for the greater rate of scale growth.

Because of the variability introduced by cut edges most of the heating experiments were carried out using samples with coated edges, mostly of size approximately 2 in. \times 2½ in. For comparison, sprayed panels also having

TABLE I.—GAIN IN WEIGHT ON CYCLIC HEATING OF ALUMINIZED PANELS AT 630° C. AND 700° C.

Testing Details	Aluminium Coating (mgm./sq. cm.)	Aluminium-Silicon Coating (mgm./sq. cm.)
a Sully <i>et al.</i> , 1,000 hr, 700° C. . .	3.8	6.2 (2.65% Si)
b B.I.S.R.A. 2,000 hr, 700° C. . .	4.1	5.3 (3% Si)
c B.I.S.R.A. 2,000 hr, 630° C. . .	1.8	2.5

coated edges were specially prepared by Metallisation, Ltd., and submitted to the same heating conditions as the hot dipped material. Sprayed specimens included coatings of commercial aluminium, aluminium alloyed with 6% silicon, and aluminium alloyed with cadmium, as used in commercial heat resisting sprayed coatings. Figs. 2, 3 and 4, show the results of the scaling resistance tests on the various specimens at the three temperatures of 620° C., 700° C. and 800° C.

The following features are notable at each temperature :

Fig. 2a. Hot Dipped Samples Heated at 620° C.—The aluminium coating is clearly better than that alloyed with 6% silicon. It is also more consistent, two samples giving results so near to each other that only one curve has been drawn.

Fig. 2b. Sprayed Samples Heated at 620° C.—The sprayed samples also show the superiority of the unalloyed coating. The beneficial effect of a preliminary heat treatment is shown.

Figs. 3a and 3b. Samples Heated at 700° C.—The relative behaviour of the two kinds of hot dipped coating (Fig. 3a) is similar to that at 620° C., the aluminium coating being both better and more consistent than that containing silicon. The improvement resulting from preliminary heat treatment of the sprayed coatings is very marked at this temperature. The sprayed coatings containing cadmium behaved very well. The hot dipped coatings show only about half the gain in weight exhibited by the sprayed coatings, although the former were appreciably thinner.

Fig. 4. Samples Heated at 800° C.—One of the samples coated with unalloyed aluminium developed a local defect after about 400 hours and the effect is seen in the graphs. The gain in weight is much greater at this temperature but the protection afforded is still very marked, the plain coating gaining an average of 9.6 mgm./sq. cm., and the silicon-alloyed coating 10.8 mgm./sq. cm.

Scaling Tests in a Current of Air Containing Some Sulphur Dioxide

Samples similar to those used in the previous tests were suspended in a vertical tube furnace. A stream of

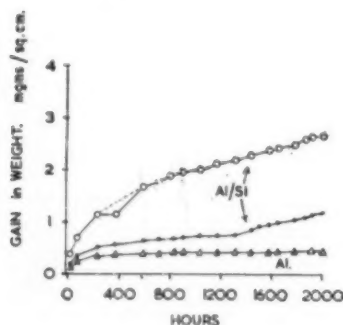
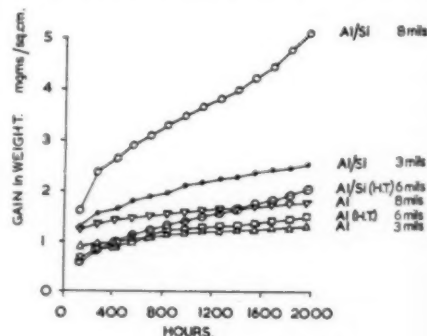


Fig. 2.—Gain in weight on heating aluminium coated panels for 2,000 hours at 620° C.: (a, on left) hot dip aluminized coatings; (b, on right) sprayed aluminium coatings.



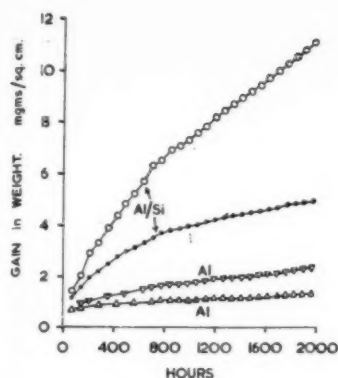
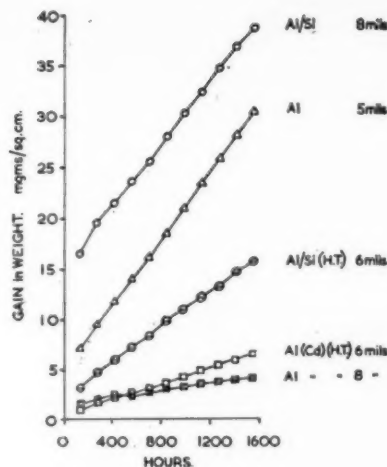


Fig. 3.—Gain in weight on heating aluminium coated panels for 2,000 hours at 700° C.: (a, on left) hot dip aluminized coatings; (b, on right) sprayed aluminium coatings.



air containing 0.1% v/v of sulphur dioxide was blown at 20 litres/min. through a packed tube in a second furnace placed below the testing furnace. The sulphur dioxide was obtained from a syphon and the air concentration was checked by iodine titration. The general arrangement of the apparatus is shown in Fig. 1. Only one such apparatus was available, and in order to test a variety of samples in a reasonable time the period of testing was reduced to 490 hours, consisting of 7 cycles of 70 hours heating.

The results of the scaling tests carried out in this apparatus at 620° C., 700° C., and 800° C. are given in Table II, which also shows for comparison the weight increase under muffle furnace conditions after 490 hours taken from the curves of Figs. 2, 3 and 4. At the lower temperatures there is no significant difference in the gains in weight in the two different conditions, but the expected difference due to increased attack in the sulphur bearing atmosphere is apparent in the 800° C. test. The superiority of the commercial aluminium coating over the aluminium-silicon alloy coating is also apparent in these sulphur dioxide bearing atmospheres.

TABLE II.—GAIN IN WEIGHT OF 50 MM. x 70 MM. PANELS WITH COATED EDGES ON HEATING FOR 490 HOURS (7 CYCLES OF 70 HOURS) IN STILL AIR AND MOVING AIR CONTAINING 0.1% V/V SULPHUR DIOXIDE

Test Temperature	Panel	Gain in Weight (mgm./sq. cm.)	
		Cyclic Heating in Muffle	Cyclic Heating in Moving Air Containing Sulphur Dioxide
620° C.	Steel hot dip coated with aluminium-6% silicon	1.1	1.4
	Steel hot dip coated with aluminium	0.4	0.3
600° C.	Uncoated steel	—	12.5
	Armco Type 1—0.7 mil coating of aluminium-silicon	—	0.7
	Armco Type 1a—1.2 mil coating of aluminium-silicon	—	0.5
	Armco Type 2—2.4 mil coating of aluminium	—	0.3
	Armco Type 2—2.4 mil coating of aluminium	—	0.3
700° C.	Steel hot dip coated with aluminium-6% silicon	3.9	2.4
	Steel hot dip coated with aluminium	1.2, 1.4	1.0
	Uncoated steel	—	213
	Armco Type 1a—1.2 mil coating of aluminium-silicon	2.4	3.0
	Armco Type 2—2.4 mil coating of aluminium	2.5	2.3
800° C.	Steel hot dip coated with aluminium-6% silicon	5.6	24.3
	Steel hot dip coated with aluminium	3.1	6.8
	Armco Type 1a—1.2 mil coating of aluminium-silicon	5.0	15.0
	Armco Type 2—2.4 mil coating of aluminium	5.2	14.3

Although the results at 700° C. and 800° C. show that the protection against scaling is adequate, the mechanical strength of mild steel is low at such temperatures and this would limit its use. For some engineering purposes involving high temperatures, such as high pressure steam generation, creep-resisting steels are used. The scaling of these steels still remains a problem and hot dip aluminizing may provide a solution. A number of creep specimens in suitable steel compositions (e.g., $\frac{1}{2}$ % Mo) have been hot dip aluminized by B.I.S.R.A. for testing elsewhere. These tests will serve to show whether the coating operation affects the creep resistance, and also to determine the scaling resistance of the coating at longer heating times.

Further Scaling Resistance Data for Aluminized Steel and Applications of the Material

Commercial experience of the heat resistance of aluminium coatings is limited in this country to sprayed coatings, but American experience has shown the value of both continuously coated strip and also fabricated articles dip coated by methods such as the Aldip or Möller processes. Dip coated material with a coating of commercial aluminium is used in the U.S.A. for diesel engine exhaust manifolds, exhaust adapters for trucks, heat exchangers, heat treatment and carburising equipment, and for domestic purposes such as oven linings and toasters. Other applications such as enamelling racks, burners, and grate-bars have also been mentioned. For

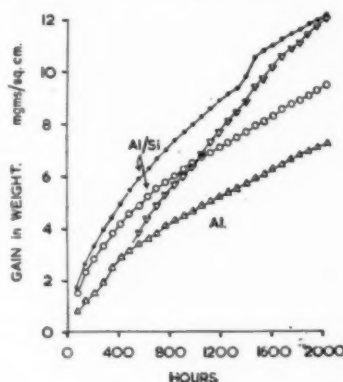


Fig. 4.—Gain in weight on heating hot dip aluminized panels for 2,000 hours at 800° C.

TABLE III.—RESISTANCE OF ALUMINIZED STEEL TO HIGH TEMPERATURES IN THE PRESENCE OF SULPHUR BEARING GASES*

Material	Treatment	Test Temperature		Test Duration (hr.)	Change in Weight † %
		° F.	° C.		
18% Cr, 8% Ni Steel	Untreated	1,350	733	24	-17.0
25% Cr, 20% Ni Steel				4	-8.3
27% Cr Steel				24	-8.4
18% Cr, 8% Ni Steel	Aluminized	1,350	732	192	0.1
Plain Carbon Steel				192	0.1
18% Cr, 8% Ni Steel	Aluminized	1,700	927	48	0.0
Plain Carbon Steel				48	0.3

* Results quoted by Whitfield and Sheshunoff from data provided by Socony Vacuum Oil Co. No information is given concerning the nature of the atmosphere, the conditions of testing, or the shape and mass of the specimens.

† After corrosion scale tapped off.

more severe conditions, true heat resisting steels high in chromium and nickel and containing also silicon, titanium or cobalt are required. Hot dip aluminizing is said to improve the behaviour even of these steels, especially in sulphurous atmospheres. The results given in Table III were quoted by Whitfield and Sheshunoff³ from data provided by Socony Vacuum Oil Co., which show the superiority of aluminized steel even compared with high alloy steels in certain sulphur bearing gases under reducing conditions.

The same authors quote the results obtained by G. Kremer and K. E. Volk⁴ on heating various chromium-silicon steels, 18-8 chromium-nickel steel, plain carbon steel, and aluminized plain carbon steel in a current of hydrogen sulphide. The benefit of aluminizing was most marked (Table IV).

For certain uses the expensive heat resisting steels have been replaced in American practice by mild steel, or low-alloy steel, protected by hot dip aluminizing. Diesel engine exhaust manifolds in stainless steel, type 321, were satisfactorily replaced in this way, using the Aldip process, with a saving of 2½ lb. of nickel and 4½ lb. of chromium for each manifold. Stainless steel was similarly replaced in military tank heat-exchangers for use at 900° F. (482° C.).⁵

In any of these applications the useful life depends upon the thickness of the coating and its continuity, as well as upon the operating conditions. A thicker coating gives a longer life but is more liable to spall on rapid heating and cooling. In such cases it is advisable to heat treat the coating before use. In this way the alloy layers and the outer layer of aluminium diffuse so as to produce a somewhat thicker coating having a more gradual change in composition from the outside inwards. The thermal stresses are then less likely to cause spalling. This diffusion process lowers the aluminium content of the outer layers and reduces the heat resistance. The heat treatment must be varied according to the initial thickness, which depends in turn upon the dipping time. This is discussed in detail by Hanink and Boegehold,⁵ who state that the minimum aluminium content for heat resistance is 10%. Samples heat treated in this way were tested by them under severe conditions, the steel base being S.A.E. 1010 (mild steel) sheet, 0.036 in. thick. This was Aldip aluminium coated for four dip times and diffusion heat treated. The oxidation test was carried out at 1,650° F. (899° C.) in an air atmosphere, forced-air cooled to room temperature: the cycle time was 20 hours. The results are set out in Table V.

It is interesting to compare the results with such coatings, consisting of iron-aluminium alloys, with the behaviour of synthetic iron-aluminium alloys, reported

TABLE IV.—WEIGHT LOSSES OF MATERIALS HEATED IN HYDROGEN SULPHIDE PASSING THROUGH THE APPARATUS AT 20 LITRES/HOUR.

Material	Weight Loss (mg./sq. cm.) After 50 Hours Heating at		
	930° F. (498° C.)	1,110° F. (598° C.)	1,290° F. (697° C.)
3% Cr, 2.5% Si Steel	65	36.5	—
6% Cr, 2.5% Si Steel	55	31.5	—
18% Cr, 2.5% Si Steel	21	55	—
18% Cr, 8% Ni Steel	32.5	90	—
Plain Carbon Steel	95	—	—
Plain Carbon Steel Aluminized	—	0.1	1.0

by Sykes and Bampfylde as long ago as 1934.⁶ Oxidation at 900° C. was greatly reduced when the aluminium content exceeded 6%. At 1,100° C. 9% aluminium was needed to produce a similar result. During the discussion of this paper it was stated that a 14% aluminium-iron alloy was in good condition after 6 months in a sulphur burning furnace at a temperature of 950° C. (Mr. I. D. Taverner). A small tray of 12% aluminium-iron alloy in a heat treating furnace showed no signs of scaling after 4 weeks at 1,050° C. to 1,100° C. (the late Dr. T. Swinden).

Failure to utilise these alloys was no doubt due to their extreme hardness and brittleness. New interest in them has been aroused by the recent development of the alloys 16-Alfenol (16% Al) and Thermenol (15/16% Al + 3% Mo), at the U.S. Naval Ordnance laboratory.⁷ Methods have been found for the production of Thermenol in a ductile form. The creep properties of Thermenol at 1,200° F. (684° C.) are said to be approximately the same as type 321 stainless steel.

Conclusions

Scaling experiments carried out on B.I.S.R.A. aluminized steel, which was prepared by a fluxless process, show that hot dip aluminium coatings so prepared provide effective protection against scaling at temperatures up to 800° C.

Hot dip coatings containing silicon were found to be less heat resistant than those of commercial aluminium only. Experiments with the American aluminized steel sheet, Armeo Aluminized, showed that its scaling resistance was approximately the same as that of the B.I.S.R.A. material.

The gains in weight shown for hot dip aluminized coatings appear in general to be less than those for heat treated sprayed coatings.

Erichsen tests could be carried out on the thinner test panels after 2,000 hours heating without any flaking of the alloy coating.

The silicon alloyed coatings retained their original lustre for 2,000 hours heating at between 500° C. and 600° C. according to the coating thickness and its silicon content.

From these experiments and those carried out by other workers, and from experience in certain industrial

TABLE V.—GAIN IN WEIGHT OF MILD STEEL PANELS, ALDIP COATED AND DIFFUSION HEAT TREATED, AFTER OXIDATION TESTS AT 1,650° F. (899° C.)

Duration of Coating Dip	Time to Failure (hr.)	Gain in Weight* (mgm./sq. cm.)
15 sec.	150	5.9
2 min.	300	3.9
4 min.	No failure after 1,000	5.1
6 min.	No failure after 1,000	6.3

* These gains in weight were quoted in % and cannot be accurately re-calculated to mgm./sq. cm. because the coating weight is not known. The values given assume a coating of 4 mils.

applications, it is apparent that there are many uses to which hot dip aluminized steel could be put with economic advantage. There is thus considerable scope for making this material available and developing its use in Britain. At present the only source of supply of aluminized steel sheet is the American Rolling Mill Corporation.

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Tonnage Oxygen Plant for Lincolnshire

A NEW piped oxygen plant, scheduled to begin production in 1957 at Scunthorpe, is expected to inspire a number of changes in the Lincolnshire steel industry, and ultimately to bring more prosperity to the town. Scunthorpe has been associated with the iron and steel industry for a century, and in the past ten years production of iron has increased more than 60% and production of crude steel has nearly doubled, so that about 1.7 million tons of iron and 2 million tons of crude steel are produced annually in the Scunthorpe area.

With the growth of the steel industry, both at Scunthorpe and in the other steel making areas of the United Kingdom, there has been over the years an increasing application of oxygen to steel works practice. Many new processes have been developed in which oxygen is used for cutting and for removing surface defects from crude steel and the like. In the last few years, owing to the initiative of the steelmakers, and in conjunction with The British Iron and Steel Research Association and the British Oxygen Company, methods have been introduced for the application of oxygen in the actual steelmaking processes. In the case of Scunthorpe, the millions of cubic feet of oxygen used by the steel industry has been brought from the Sheffield area—50 miles away. With the increasing usage, particularly in the steel furnaces themselves, it has become appropriate to set up oxygen manufacture locally. The plant will be what is known as the tonnage type, i.e., for manufacture on a large-scale, and suitable for distribution by pipeline. The process is to one of the British Oxygen Company's own Rescol designs.

British Oxygen have based their belief in the need for a new tonnage oxygen plant at Scunthorpe on this main point: that if the steel industry is to derive the maximum benefit from the use of oxygen in steelmaking, it must be able to procure an adequate and reliable source of supply at a cost which will enable it to obtain increased steel production on an economical basis. An important feature of tonnage oxygen, is the considerable reduction in oxygen costs, which will be reflected in greater and cheaper steel output.

At Scunthorpe the initial installation will comprise a plant with a productive capacity of 200 tons of oxygen a day—or about 36,000,000 cu. ft. a week. The site selected by the British Oxygen Company for the new works is in the Warren Road area of Scunthorpe—almost mid-way between the Normanby Park steel works and the Appleby-Frodingham, Redbourn and Firth-Brown group of steel works. Such a centrally-situated plant will more easily be able to run a direct pipeline supply to individual steel works. The introduction of the B.O.C. tonnage oxygen plant will therefore enable the steel industry in Scunthorpe to develop to the full the use of oxygen in steelmaking to meet future increases in the demand for semi-finished steel products.

Although with an oxygen plant of this character, of large-scale and with a high element of automatic control, there is likely to be only a moderate increase in the direct use of local labour, steel manufacturers anticipate that the new oxygen project will bring increased prosperity to Scunthorpe.

Automatic Selective Charging of Blast Furnaces

AN automatic selective charging system for blast furnaces, which is claimed to increase considerably the output of the furnaces, while at the same time reducing the fuel consumption, has been in operation for more than a year at the Oxelösund Ironworks, just south of Stockholm. Another advantage of this Swedish invention, already patented in leading steel-producing countries and launched on the market by the Stockholm engineering firm of T. An. Tesch AB, is the uniform operation.

It is a fact well-known to furnace experts that in conventional shaft furnaces of circular horizontal section, even if the charged stock has been evenly distributed, the ascending gases seek the line of least resistance and preferably follow the walls of the furnace. Consequently, the volume of the furnace shaft is not efficiently utilized, and the gases cannot act at full capacity. They may also form "channels" in the stock, with resultant irregularities in the operation, "slips" and "hangings" occurring now and then.

The new Swedish system eliminates these drawbacks, as the stock to be charged—iron ore, sinter, limestone, coke, etc.—is selectively and automatically distributed in the furnace shaft in such a manner that the gases on their way upwards meet the same resistance in penetrating the charge at any point of the horizontal surface of the charged material. The gases near the walls are checked by a charge of a denser nature, or of more abundant quantity, whereas in the intermediate and central parts of the shaft the gases meet stock of coarser and more permeable character, which facilitates their passage. This results in a uniform flow of gases and enables the utilisation of the full cross-section of the furnace.

In a report on activities in 1954, the Oxelösund Ironworks states that the capacity of the new furnace was 15% higher than that of the old one. A further improvement in output was noted during the first half of the current year. The volume of the new furnace is somewhat smaller than the old one, while the same stock, blowing engines, etc. are still used. The operation is said to have been very uniform, "slips" and "hangings" having been practically eliminated.

NEWS AND ANNOUNCEMENTS

Mond Nickel Fellowships 1955

THE Mond Nickel Fellowships Committee announces the following awards for 1955:—

D. H. BUTLER (The Phosphor Bronze Co. Ltd.).—To study the production of copper and its alloys, with particular attention to foundry methods, in the United Kingdom, on the continent of Europe and in America.

R. W. N. DRON (Rhoanglo Mine Services, Ltd.).—To study the organisation of research and its relation to production in extraction metallurgy in the United Kingdom and North America.

W. F. DUNCAN (The British Aluminium Co. Ltd.).—To study the design, layout and operation of continuous strip mills, considering in particular metal behaviour, properties and quality, roll lubrication and cooling and the development of automatic controls.

R. H. HANNAFORD (The British Iron and Steel Research Association).—To study organisation and practice in the ferrous foundry industry in the United Kingdom, Europe and the United States, with particular reference to layout, mechanisation and the application of management techniques.

R. J. HARBORD (John Lysaght's Scunthorpe Steelworks Ltd.).—To study the development of continuous casting in the non-ferrous industry and its application to the production of steel.

Metals at Low Temperatures

IN order to bring to the attention of metallurgists aspects of a recent low-temperature conference in Paris that related to metals, the Metal Physics Committee of the Institute of Metals has arranged a meeting to be held in London. After a short introduction by Sir Francis Simon, C.B.E., F.R.S., Professor of Thermodynamics, The Clarendon Laboratory, Oxford, explaining why low temperatures are becoming of increasing importance to the metallurgist, Dr. P. L. Smith and Dr. H. M. Rosenberg, of the Clarendon Laboratory, will make individual reports on the Paris Conference. The speakers will review some of the work on thermal and electrical conductivity, the specific heats of metals, and some of the mechanical properties at low temperatures (e.g., internal friction, elastic properties, fatigue, etc.).

The meeting will be held at 4, Grosvenor Gardens, London, S.W.1, on Wednesday, 7th December, 1955, at 6.30 p.m. Visitors will be welcome. Tickets of admission are not required.

New B.S.I. Appointments

NEW Chairman of the General Council of the British Standards Institution is SIR HERBERT MANZONI, C.B.E., Engineer and Surveyor of the City of Birmingham since 1935. The election of Sir Herbert, who has been largely responsible for the Birmingham Development Plan and many important building projects in Birmingham, was announced at the Annual General Meeting of B.S.I. held last month at the Institution's London headquarters. For twenty years Sir Herbert has played an important part in the development and application of standardisa-

tion techniques in the building and civil engineering industries.

At the same meeting SIR ROGER DUNCALFE, Chairman of British Glues and Chemicals, Ltd., and well-known for his industrial and public services, was re-elected President of B.S.I., and MR. JOHN RYAN (Vice-Chairman of the Metal Box Co. Ltd.) was elected as Vice-President on completion of his three-year period of service as Chairman of the General Council.

Another important appointment was that of SIR STANLEY RAWSON, Vice-Chairman of John Brown & Co. Ltd., who becomes Chairman of the B.S.I. Engineering Divisional Council. He succeeds MR. S. J. HARLEY (Coventry Gauge & Tool Co. Ltd.) in directing the largest individual section of B.S.I.'s work on both national and international standardisation. Sir Stanley was Government representative at a Conference on fundamental engineering standards in 1952, between Great Britain, America and Canada, and has led delegations at international meetings working for the alignment of national standards for machine tools.

The 1955 Viscount Nuffield Paper

"BRITAIN'S ENERGY PROSPECTS" will be the subject of Dr. G. H. Daniel (Chief Statistician, Ministry of Fuel and Power), when he presents the 1955 Viscount Nuffield Paper to the Institution of Production Engineers at the Royal Institution, Albermarle Street, London, W.1, on Thursday, 15th December, 1955, at 6.30 p.m. The paper will address itself to the question of whether shortage of fuel and power will set limits to the expansion of industrial activity. It will consider the present level of energy consumption, how this has grown in the past and how it might continue to grow in the future if optimistic expectations about the expansion in standards of living are realised. In considering the future, attention will be given, among other things, to the possible effects of automation on the demand for energy. The paper will deal with the relative attractiveness and prices of the principal sources of energy, and will review some of the factors determining their supply. The problems of meeting this demand will then be discussed. Application for tickets of admission to the meeting, and preprints of the paper when available, may be made to the Secretary of the Institution of Production Engineers, 10, Chesterfield Street, London, W.1.

Special Libraries Association Scholarships

THE Scholarship and Student Loan Fund Committee of Special Libraries Association announces two \$500 scholarships to be granted for the academic year 1956-1957 for graduate study in librarianship, leading to a degree at an accredited library school. Applicants must be college graduates of high academic achievement who need financial assistance in obtaining the professional education necessary for work in the special library field.

The Special Libraries Association is an international organization of librarians working in libraries and other information centres concerned with special subjects and serving business, industry, science, social welfare,

government and the arts. The Association has over five thousand members in twenty-nine chapters throughout the United States and Canada, as well as members in other countries.

Application forms and details of eligibility for the scholarship award may be obtained from the Executive Secretary, Special Libraries Association, 31, East Tenth Street, New York 3, N.Y. Applications must be received by the Scholarship and Student Loan Fund Committee of the Association by March 1st, 1956. The awards will be announced at the annual convention of the Association at Pittsburgh, Pennsylvania, in June 1956.

Translation Monthly

THE Special Libraries Association announces a new monthly serial, *Translation Monthly*, at a price of \$5.00 a year. It fills a long-felt need of its members and many professional groups who are required to keep up with developments reported in foreign periodicals. It is an 8-page bibliography, listing alphabetically by author current acquisitions to the S.L.A. Translation Pool, which is located at The John Crerar Library, in Chicago.

The S.L.A. Translation Pool is a rapidly growing collection of translations deposited by government agencies, technical societies, universities, industrial companies and individuals. They are donated for use by others interested in the same material for their private use and research only. Copies are made available at the regular photocopying prices of The John Crerar Library. The material in the Pool is from all languages but Russian, which translations are available at the Library of Congress, Science Division, Washington 25, D.C.

Publication of the Serial will begin as soon as 310 orders have been received. Orders and cheques should be sent to: S.L.A. Translation Pool, The John Crerar Library, 86 East Randolph Street, Chicago 1, Illinois. Cheques should be made payable to *Translation Monthly*. Subscriptions are accepted only for a calendar year, beginning with Volume 1, Number 1, January, 1955.

Welding Design Course in Glasgow

A FURTHER Course on the Design of Welded Structures is again to be held in Glasgow, following the success of that held there in 1954. The course will commence on 10th January, 1956, at The Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, and the lectures will be held on Tuesday and Wednesday evenings from 7 p.m. to 8.30 p.m. over a period of seven weeks. The course is arranged to assist designers and draughtsmen of welded structures, and the lectures will be given by members of the Quasi-Arc technical staff. On the final evening the guest speaker will be Professor W. T. Marshall, of Glasgow University, who will be dealing with the plastic design theory. Further details along with the enrolment form can be obtained on application to the Constructional Design Department, Quasi-Arc, Ltd., Bilston, Staffs.

Iron and Steel Export Licence Change

THE Board of Trade announce that the Open General Licence which authorises the export of certain iron and steel goods valued at more than £20 per ton to any destination other than China, Macao, North Viet Nam or Tibet is revoked and replaced by a new Open General Licence which raises this value limit to more than £25

per ton. This licence came into operation on 9th November, 1955, and individual licences are now required for exports where the value is £25 per ton or less. The iron and steel goods are those specified in Group 6(2) of the First Schedule to the Export of Goods (Control) (Consolidation) Order, 1955. Enquiries regarding this licence should be made to the Export Licensing Branch, Atlantic House, Holborn Viaduct, London, E.C.1. (Telephone City 5733). Copies of the Open General Licence (price 2d. each, by post 3½d. each) may be obtained from H. M. Stationery Office, Kingsway, London, W.C.2, and branches.

Copper-Cobalt Ore Mine

CHIBULUMA MINES, LTD., announce that the hoisting of copper-cobalt ore from its mine at Kalulushi, Northern Rhodesia, has now begun, Mr. R. L. Prain, O.B.E., the Chairman of the Rhodesian Selection Trust, Ltd., rang away the first skip at an informal ceremony at the shaft head on October 20th. Newest mine of the Rhodesian Selection Trust Group of Companies, Chibuluma is nine miles west of Kitwe in the Northern Rhodesian Copperbelt. When in full production it is expected to produce approximately 16,000 tons of copper and 500,000 lb. of cobalt a year.

Ore hoisted during the next few months will be stockpiled until the completion of a concentrator on the site. Extensive research into the methods of separating the copper and cobalt minerals from the ore has been made in the laboratories of Rhodesian Selection Trust Services, Ltd., who are consulting engineers of the company. The results of this research have determined the design and equipment of the concentrator, which will be ready for operation early next year.

When the concentrator is in operation the ore will first be crushed and ground. It will then be treated in flotation machines and conditioned so as to promote a separation giving a copper mineral concentrate and a cobalt mineral concentrate. The copper concentrate will be smelted elsewhere in the Copperbelt, while the cobalt concentrate will be treated in a plant which is being built by Chibuluma Mines, Ltd., near Ndola. Estimated ore reserves of the Chibuluma mine are 7.3 million tons at an average grade of 5.23% copper and 0.25% cobalt.

International Sales Conference

A KENT Sales Conference held at Luton on 12th and 13th October discussed plans for the further expansion of home and export marketing beyond the present record levels. In a very full programme, examination was made of new products and applications contributing to the already wide Kent range of industrial instruments and automatic controllers. In addition, area selling policy was reviewed, with emphasis on the nationally vital export fields. The greatest satisfaction was expressed by the 80 or more members of the Conference in the impressive revelations of future products and policy.

Exhibition of X-Ray Photography

To commemorate the sixtieth anniversary of the discovery of X-rays, an exhibition of X-ray photography, organised by the Royal Photographic Society, will be held at its Kensington home at 16, Princess Gate, London, S.W.7, from December 13th to 22nd, 1955. The exhibi-

tion is being organised in conjunction with the British Institute of Radiology, the Institute of Physics Non-Destructive Testing Group, the Institute of Physics X-Ray Analysis Group, the Institute of X-ray Technology, the Society of Industrial Radiology, the Society of Non-Destructive Examination, and the Society of Radiographers, and will be opened by Mr. W. E. Schall at 4.30 p.m. on Tuesday, 13th December. Lectures on X-ray photography and its applications will be given during the exhibition by Professor J. D. Bernal, Professor J. E. Roberts, Mr. Cuthbert Andrews, and Mr. W. E. Schall. Admission to the exhibition is free, and it will be open from 10 a.m. to 7 p.m. each week day, and 10 a.m. to 5 p.m. on Saturday.

Welding Equipment Merger

APART from the great increase in the use of existing welding methods since before the war, the need for faster welding and efficient fabrication of the newer materials has led to developments in the processes themselves, and to the introduction of new methods. Manual arc welding with covered electrodes has long been a well established process, and the automatic welding processes, using continuous coils of covered electrode or bare wire with a powder fed separately to the arc, are now used extensively. Later developments include the inert-gas processes, using bare wire with the arc shielded by a stream of inert gas, which are particularly applicable to non-ferrous materials and stainless steels, and are now finding their uses in steelwork.

By the combination of the activities of the Quasi-Arc Co., Ltd., and Fusarc, Ltd., in a new company—Quasi-Arc, Ltd.—users of arc welding will have available an organisation with a comprehensive manufacturing and marketing service, with over 40 trained welding engineers established in industrial centres in the United Kingdom, selling organisations under direct control through 14 associated companies in Commonwealth countries, and 30 agents and representatives throughout the rest of the world. The activities of the new company will cover the following well-known processes: Quasi-Arc, Fusarc, Unionmelt, Sigma, Heliarc and Twin-Arc.

Colloquium on Spectroscopy

THE Sixth International Spectroscopical Colloquium will be held in Amsterdam from 14th to 19th May, 1956. As usual, the Colloquium will cover both emission spectroscopy and absorption spectroscopy, mainly with a view to practical application in analysis. Further information will be sent on request to the office of the Colloquium: Laboratorium voor Analytische Chemie, 125, Nieuwe Achtergracht, Amsterdam, C.4.

Visitors by Helicopter

EDWARDS HIGH VACUUM, LTD., in their drive for exports are to use helicopters to ferry overseas visitors from London Airport to their factory in Crawley, 30 miles away. Helicopter Services, Ltd., who provide the flights, have examined the factory grounds and selected a suitable landing place close to the offices. Visitors will walk straight into a Conference Room and the helicopter flight will differ little from a car journey in convenience, save in the all-important matters of time and freedom from traffic jams.

Personal News

MR. J. M. WILLEY, General Manager of Murex Welding Processes, Ltd., has been appointed to the Board of Directors of the Company.

MR. R. KENT, Sales Director of George Kent, Ltd., is at present on a month's visit to South America where he is visiting Kent agencies and principal customers in Brazil, Uruguay, Argentina, Venezuela, Cuba and Mexico.

MR. H. V. POTTER has retired from his position as Managing Director of Bakelite, Ltd. Mr. Potter will continue as Chairman, but will be succeeded as Managing Director by MR. G. W. HODDS.

SIR BERNARD KEEN, F.R.S., has been appointed Scientific Advisor to Baird & Tatlock (London), Ltd. Until recently he was Director of the East African Agriculture and Forestry Research Organisation.

MR. R. A. HENDERSON and MR. J. L. E. SMITH have joined the Board of the Solartron Electronic Group, Ltd.

MR. J. R. HANDFORTH and MR. R. T. RAVEN have been appointed Directors of Birmetals, Ltd., and Birmabright, Ltd.; Mr. Handforth as Technical Director, and Mr. Raven as Works Director.

MR. C. C. BATES, Chief Welding Engineer of Welding Supervision, Ltd., and Welding Consultant to Costain-John Brown, Ltd., has been visiting the United States and Canada on an extended business tour, during the course of which he presented to the 1955 Fall Meeting of the Metal Exposition and Congress in Philadelphia a paper on the "Gamma Radiographic Control of Welded Transmission Pipelines."

MR. T. SAMSON has been appointed Chief Draughtsman of the Trackwork Department of Edgar Allen & Co., Ltd.

MR. G. G. HOUSTON has taken up an appointment as representative of Marsh Brothers & Co., Ltd., assisting MESSRS. O. W. and O. B. MORTIMER in the West Riding of Yorkshire. Mr. Houston will also pay regular visits to the North East Coast area.

Obituary

WE regret to record the death at the age of 78 of Mr. E. G. King, Chairman of The Louis Cassier Co., Ltd.—a subsidiary of the Associated Iliffe Press. Mr. King entered journalism in 1894 when he joined the London staff of an American journal, *Cassier's Magazine*, devoted to engineering and shipbuilding in all its branches. When Mr. Louis Cassier, owner of the paper, died in 1906, Mr. King acquired control of the Company and became its Managing Director. Then came a period of expansion during which other publications were introduced including *Metal Industry* and *Iron and Steel*: to these were added a number of handbooks and directories. After various changes in the title of *Cassier's Magazine* itself, Mr. King decided to rename it *Mechanical Handling* because he felt that developments in this field, then taking place in the United States, were certain to develop equally in Britain: that was in 1930. In 1942, Mr. King handed over the control of the Company to Associated Iliffe Press.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Molten Metal Temperature Measurement

CAMBRIDGE INSTRUMENT CO., LTD. have recently introduced thermocouples suitable for measuring the temperature of molten non-ferrous metals—brass, bronze, aluminium alloys, etc.—and cast iron. For temperatures up to 1,100° C., thermocouple elements of Chromel/Alumel, approximately 36 in. long, are used, threaded through a mild steel tube with a junction box at one end and a removable closed-ended graphite sheath at the other. Its self-lubricating properties prevent the sheath from binding when it is subjected to heat: it is therefore easily replaceable. Below the junction box, the mild steel tube is fitted with a shield to protect the cold junction of the thermocouple from the heat radiated from the molten metal.

For higher temperatures—up to 1,550° C.—the thermocouple elements are of rare metals (platinum-rhodium) and the mild steel tube is replaced by one of nickel-chrome. The element wires are about 4 ft. long, the surplus wire being wound on small reels contained in the junction box. The device makes allowance for the removal of the thermocouple tip when deterioration occurs. The average lag of both types is 25-28 seconds when the graphite sheath is new, falling to 18-20 seconds as the sheath wall gets thinner with use. Asbestos-covered compensating leads are used to connect the thermocouple to the indicator or recorder, thus rendering the outfit independent of fluctuations in the temperature at the junction box cold junction.

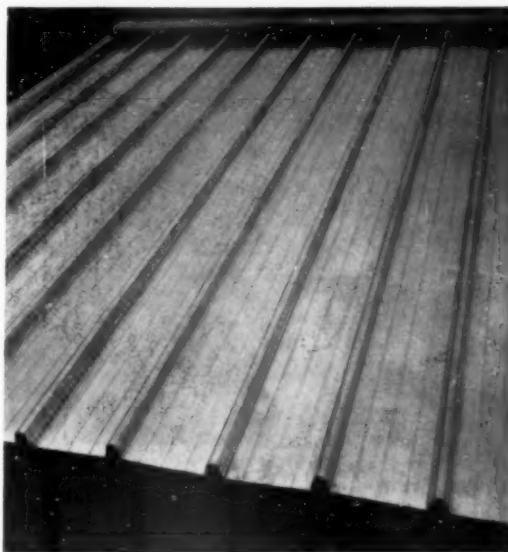
Cambridge Instrument Co., Ltd., 13 Grosvenor Place, London, S.W.1.

Aluminium Building Sheet

NORAL Snaprib sheet, a new aluminium building sheet, incorporates a simple, unobtrusive snap-joint along the full length of overlapping corrugations and is secured to the purlins by concealed clips. It therefore provides a continuous metal cladding which, with no holes or fixings exposed to the weather, is entirely leak-proof, and, having the additional benefit of aluminium's resistance to corrosion, requires no maintenance. Moreover, with a range of specially-designed flashing accessories, it comprises a complete system, of good appearance and suitable for the roofs of houses, either conventional or prefabricated, and for the roofing and siding of industrial buildings.

Erection is easy and quick, the sheets being clipped simply but securely to the purlins and snapped together at the side lap, no drilling or precise location being necessary. Dismantling is also easy, individual sheets being removed by a simple tool, both the sheets and fixings remaining undamaged and therefore in perfect condition to be used again in other installations.

Snaprib sheet is roll-formed from 22 s.w.g. Noral 3S alloy in the fully hard temper, and is supplied in any length up to 20 ft. Even in the largest size it can be



easily handled owing to its lightness and simplicity of fixing; it will therefore cover all except the very biggest roofs in a single course, the absence of overlaps improving both appearance and resistance to the weather. Where a second course is necessary, special overlapping sheets are used that are as easy to install and as weathertight as a single course. The system also readily lends itself to under- or over-purlin insulation.

Tests have shown that Snaprib sheet, fixed as recommended, will safely withstand 30 lb./sq. ft. pressure or suction loading over a 5 ft. purlin spacing, this being the maximum recommended spacing for roofs. It is available in natural finish, in a Pylumined finish, or in an Alclad finish.

Northern Aluminium Co., Ltd., Banbury, Oxon.

Electrode Drying Ovens

RECENT research has established the importance of drying and/or preheating arc welding electrodes for certain classes of work, with a view to eliminating defects and improving results. Standard ovens for the temperature range concerned are available, but Siemens-Schuckert have now produced two furnaces specially designed for this purpose.

The Type VWO 9/18 transportable vertical oven has been designed for use in places where floor space is of primary importance, for example, in the shipbuilding industry where welders carry out a great deal of work on scaffolding. The heating space of 9 in. dia. x 18 in. high has a capacity of 80 lb. of electrodes. The door is operated by a foot pedal to facilitate easy removal of the rods, and the oven is fitted with substantial handles by means of which it can be moved or hoisted on to scaffolding. The rating of the oven is 1 kW. and the



Type VWO 9/18 vertical electrode dryer

temperature can be adjusted in the range 75°–300° C. by means of a thermostat.

The Type WO 18/20 horizontal oven has been designed for workshop use, and large quantities (3 cwt. approx.) of electrodes can be stored in it at temperatures between 75° and 300° C. Like the VWO 9/18, the temperature can be thermostatically controlled, and the rating of 1½ kW. means that it, also, is suitable for connection to the supply through a normal power plug.

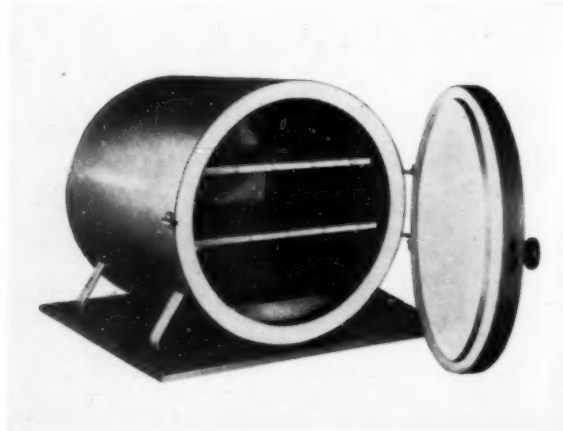
Both furnaces are fabricated in mild steel plate, suitably reinforced, and the heating chamber is insulated with high quality insulating material to ensure that maximum thermal efficiency is obtained.

Siemens-Schuckert (Great Britain), Ltd., Faraday Works, Great West Road, Brentford, Middlesex.

Water Cooling Units

In many parts of the country it is becoming increasingly difficult to obtain adequate supplies of chemically-suitable water for cooling industrial plant and this has led Philips Electrical, Ltd., to introduce a complete range of closed-circuit water cooling systems. Water is continuously pump-circulated and there are only evaporation losses to replace, so that considerable reduction in water consumption is possible. Intended primarily for use with Philips high-frequency generators, the equipment is equally suited to many other cooling requirements.

Systems operate from storage tanks with capacities varying from 25–300 gallons (according to requirements) and with radiator dissipation ranging from 3–240 kW. Air cooling is provided by a motor-driven fan. Units are available in "skeleton" form—with the radiator, fan, pump and motors mounted on rubber bases upon a mild-steel framework—or as completely self-contained units with storage tank and all associated equipment built into a cabinet. The tank can contain mains water, if suitable, chemically-treated local water, or distilled



Type WO 18/20 electrode dryer

water. It is fitted with a visual gauge, float switch, thermostat and pressure switch. A by-pass cock and pressure gauge are fitted for adjusting flow and pressure to the requirements of any particular generator. The 80 kW unit is typical of the complete range. Capable of handling up to 1,300 gal./hr. at a maximum pressure of 55 lb./sq. in., it can dissipate 80 kW. at a maximum outgoing temperature of 35° C. and maximum ambient temperature of 25° C.

Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Wet Water for Fire Fighting

A NEW wet water composite pressure charge for use in first-aid fire fighting on porous materials has been placed on the market by Nu-Swift, Ltd. In fire fighting, it has been found that plain water is handicapped by its surface tension, which prevents or retards plain water from spreading and penetrating into porous materials, and, therefore, hinders the cooling of hot spots which, in the case of dangerous, deep-seated fires, is more important than extinction of surface flames. Otherwise, re-ignition from within may occur. Wet water has been tested in the United States in fire fighting and its use on deep-seated fires is said to bring about an increase of 50% compared with the fire fighting efficiency of ordinary water.

The Nu-Swift wet water concentrate, which is of the non-ionic type, is held in the composite pressure charge in a plastic bag which is burst instantaneously and automatically when the extinguisher is operated. Claimed to be the first composite wet water pressure charge in the world, it has been approved by the Fire Offices' Committee, but only for use in the Nu-Swift 2-gallon Universal (Royal Navy) Extinguisher, Models 1301 and 1300.

Nu-Swift, Ltd., Elland, Yorkshire.

WICKMAN, LTD., have assumed the sole agency for the products of Arthur Scrivener, Ltd., Tyburn Road, Birmingham. This company manufactures a range of single and duplex surface grinding machines, automatic horizontal rotary grinding machines, centreless grinding and piston grinding machines, and a profile turning lathe. It also manufactures a number of special purpose grinding machines for grinding brake shoe linings, valve rockets, tappets, pistons, etc.

CURRENT LITERATURE

Book Notices

NON-FERROUS FOUNDRY METALLURGY

Edited by A. J. Murphy. 497 pp., numerous illustrations. London, 1954, Pergamon Press, Ltd. 70s.

UNTIL comparatively recently, foundry work was regarded mainly as an art, with the inherent and acquired skill of the craftsman as the all-important factor in determining the quality of the product. As Professor Murphy points out in his preface, the melting and casting of non-ferrous alloys was to a large extent neglected by scientific metallurgists until 10 or 15 years ago, but since then these aspects have engaged the attention of some of the most able investigators, whose researches have laid a secure foundation for a scientific approach to the technical problems and opportunities in foundry work. There is already a trend towards the employment of increased numbers of trained metallurgists in the non-ferrous foundry industry, and it is to them that this book is primarily addressed, in the hope that it will help them in translating scientific theory into successful practice.

As may be seen from the details set out at the head of this notice, "Non-Ferrous Foundry Metallurgy" has been edited by Professor A. J. Murphy, who had many years experience in the non-ferrous foundry industry prior to taking up an appointment at Birmingham University as Professor of Industrial Metallurgy and head of a department where science and practice are closely related. He is, therefore, an admirable choice for the task, and he has been fortunate in gathering together a number of authoritative writers to deal with the various aspects of the subject. Excessive repetition, which might result from such a procedure, has been successfully avoided by the co-operation of the several authors in an agreed common programme.

Following an introductory chapter giving a brief outline of the principal properties of metals and alloys, their significance in the operations of melting and casting, and their influence on the characteristics of cast products, there are sections on the properties of liquid metals, the solution of gases in liquid metals, and solidification. Throughout references are given to published work on the subject under discussion, and in these early chapters on fundamentals, which take up about a third of the book, the lists are quite extensive.

On the production side, there is a section on non-ferrous foundry technology, in which the production of metal castings, the casting of ingots for subsequent working, and industrial melting of non-ferrous metals and alloys are dealt with in turn. This is followed by a section on the properties and testing of castings, which opens with a discussion of the difficulties which must be overcome in the production of serviceable castings. The influence of form and environment on the endurance of castings is next considered, endurance being used in its widest sense and not—as is often the case in relation to metals—in the sense of fatigue life. Finally there are sections dealing with the measurement of gas content and non-destructive testing.

The last quarter of the book is devoted to a consideration of the foundry metallurgy of particular alloys, grouped together in seven sections, dealing, respectively, with those based on copper, nickel, aluminium, magnesium, zinc, tin and lead, and silver, gold and platinum.

THE MINING AND DRESSING OF LOW-GRADE ORES IN EUROPE

Report of O.E.E.C. Technical Assistance Mission No. 127, 340pp., numerous illustrations. Obtainable from H.M. Stationery Office and other organisations handling O.E.E.C. publications. 18s.

THROUGHOUT the Western world, the richest and most easily worked mineral deposits are becoming exhausted, and mining engineers are turning their attention to the working of low-grade ores and to the recovery of metals from slag heaps. Since this is a problem which will become more acute with every passing year, the O.E.E.C. has arranged for surveys to be made by mining and ore-dressing engineers of the most modern techniques in this field. In April and May 1953, twenty-four of the leading European experts visited ore-dressing plants and laboratories in five European countries, and last year a team composed of approximately the same members visited similar installations in the United States. The report of the first of these Missions is now available; the companion volume dealing with American techniques will, it is hoped, be published shortly.

The report of the European Mission is in two parts. Part I discusses the general economic and technical aspects of the low-grade ore problem, including those of research facilities and recruitment and training of engineers. Part II deals in detail with the various processes of comminution and separation used in Europe. But larger than the report, and quite as useful, are the Appendices, which give flowsheets and short technical descriptions of some 28 plants and research establishments visited by the Mission. They also include resumés of the papers presented at the symposia which they held in England, Sweden, Germany, Italy and France.

A full bibliography is a further attractive feature of this interesting and timely document.

Trade Publications

THE INTERNATIONAL MEEHANITE METAL COMPANY, have recently produced an illustrated booklet entitled "Meehanite in the Service of Industry". Following a brief introduction to Meehanite, in which it is pointed out that Meehanite castings are produced in a number of different types, each processed to meet a particular need, and that they may be broadly divided into four groups: general engineering, heat resistance, wear resistance, and corrosion resistance, examples are given of the use of these materials in aircraft, automobiles, armaments, diesel engines, crankshafts, machine tools, dies, presses, pressure casting, preheaters, refrigerators, valves, shipbuilding, mining, power stations, pumps, furnaces, chemical plant, oil refineries, the iron and steel industry, railways and roads, printing, textile

machinery, cranes, agricultural implements and bridges. Many of these applications are comparatively new, and copies of the booklet may be obtained from International Meehanite Metal Co., Ltd., Meerion House, 4, Downside, Epsom, Surrey.

A LEAFLET issued by The Midland Saw & Tool Co., Ltd., describes the new Midsaw "Minor" band sawing and filing machine. This is a small machine which has big possibilities in sawing and filing work, and is equally useful to small users with limited resources or as the little "pony" for the big shop. The saw wheels are $16 \times 1\frac{1}{2}$ in., and the worktable 18×18 in. Maximum thickness of work is 8 in., and the horizontal capacity (throat) 15 in. The machine speed is infinitely variable from 60-500 ft./min. Band filing is claimed to have a number of advantages over reciprocating filing, and in this machine the filing band consists of 26 files and one special recessed jointing file carried on a steel band. The filing bands are made in three widths: $\frac{3}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$ in.; and two shapes, flat and contour.

FOSECO Foundry Practice No. 121 contains, as usual, a report on an investigation carried out by the Company's service personnel. On this occasion it deals with hardness trouble in grey iron castings. Other items featured in this issue include practical tips for moulding, common green sand foundry faults, copper-tin alloys, and an unusual cause of waster castings.

WE have received from British Aluminium Co., Ltd., brochures dealing with various types of Rigidal corrugated aluminium sheet manufactured by the Company. These include Mansard, 3 in. pitch, Industrial Trough T, and Industrial Trough L.T. types. In each brochure, details are given of dimensions and weights, together with recommendations as to the purposes for which each is most suitable.

IN spite of the present widespread and rapidly increasing use of aluminium, its excellent forming characteristics and the methods of taking full advantage of them are not yet as widely appreciated as they might be. With a view to remedying this situation, Northern Aluminium Co., Ltd., have reprinted in book form a series of articles on the subject by Mr. H. Hinxman, one of their development engineers, which aroused much interest when they first appeared in *Sheet Metal Industries*. In ten chapters, copiously illustrated, this 64 pp. book, entitled "The Forming of Aluminium Sheet" presents in a readily applicable, essentially practical form, the fundamental aspects of the material. The subjects dealt with in its pages include characteristics of the metal and its manipulation in bending, spinning, deep drawing, processing, drop hammer forming, rubber die pressing, stretch forming, unit forming, blanking, piercing and various supplementary operations. All are illustrated by examples from actual practice, which are described in detail.

WE have received from Armstrong Whitworth (Metal Industries), Ltd., their latest technical leaflet dealing with Closeloy rolls. The leaflet gives a brief resumé of the Closeloy range which includes types made in carbon and alloy steels and in various grades of iron, including spheroidal graphite iron. Various types cover rolls suitable for such a variety of operations as heavy duty blooming of steel ingots and the cold rolling of copper, brass, aluminium and steel sheet and strip to a fine finish. Constant checking and inspection takes place at

all stages of manufacture and a final examination with the aid of ultrasonic testing equipment ensures freedom from internal ruptures, cavities and other defects.

LEAFLET No. MFD 4/3.55/08, recently issued by the Metal Finishing Division of The Pyrene Co., Ltd., deals with Pyroclean No. 101 Cleaner, which is an emulsion-type degreasing agent used in aqueous solution and operated at around 160° F. It is intended for use in the cleaning section of fully automatic metal finishing plant like "Spra-Bonderising" installations, but it can also be used for component cleaning in any type of spray cleaning machine. Details are given of its uses, and prices are quoted for production and trial sizes.

AN illustrated leaflet issued by Gibbons Brothers, Ltd., Dudley, shows the types of furnaces and charging machines made by the Company and its Associates, and lists their applications in various industries. They include plate and angle furnaces, bell type furnaces, continuous furnaces, steel heat treatment furnaces, disc hearth and roller hearth furnaces, bogie hearth furnaces, rotary hearth furnaces, forge furnaces and melting furnaces.

THE British Gear Manufacturer's Association numbers among its members the principal British manufacturers of machine cut gears, enclosed gear drives, and other power transmission equipment related thereto. Also associated are companies manufacturing machines or tools for gear making. The Association has recently issued a Buyers' Guide which gives particulars of the products of each member company, indicating the range of sizes in which each type is made. Copies may be obtained from the Secretaries of the Association, Peat, Marwick, Mitchell & Co., 301, Glossop Road, Sheffield, 10.

IN the last few years the advent of the fluxless, shielded-arc welding processes has revolutionised the joining of aluminium and its alloys. The older oxy-gas and coated-electrode methods, with their disadvantages of the need for careful flux-removal and, in the first case, of a wide heat-affected zone, are rapidly being superseded. The speed and reliability of welding now possible are extending the use of aluminium to many applications in which it could not previously compete with easily-welded metals such as steel. A brochure "Welding Aluminium," recently issued by Northern Aluminium Co., Ltd., Banbury, gives information on the modern argon tungsten arc and inert metal arc processes, including data on suitable alloys and on weld strength. The latter part of the book consists of tables giving in detail the recommended procedures for various types of weld.

Books Received

"Ultrasonic Engineering." With particular reference to High Power Applications. By A. E. Crawford. 344 pp. inc. index and numerous illustrations. London, 1955. Butterworths Scientific Publications. 45s. net; by post 1s. extra. The American edition of this book is published by Academic Press, Inc., 125, East 23rd Street, New York 10, N.Y.

"Tungsten"—Its History, Geology, Ore-Dressing, Metallurgy, Chemistry, Analysis, Applications, and Economics. By K. C. Li and C. Y. Wang. Third Edition. 506 pp. inc. index. New York and London, 1955. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 112s. net.

LABORATORY METHODS

MECHANICAL • CHEMICAL • PHYSICAL • METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

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The Application of Spectrographic Solution and Powder Methods to the Analysis of Miscellaneous Samples*

By P. T. Beale† and Daphne A. Poynter†

(Communication from The British Non-Ferrous Metals Research Association)

Solution and powder methods of spectrographic analysis have the great advantage of ease and reliability in the preparation of synthetic standards. They have been applied to a wide range of materials, which would have proved difficult or impossible to analyse by conventional spark-to-solid techniques. The article describes in detail a number of methods which have been found useful, giving particulars of practical experiences with the various techniques and specific applications.

SPECTROGRAPHIC analysis of metallic samples depends for its successful application on the availability of chemically analysed standards of a composition similar to the samples, and on the rigid control of the form and metallurgical condition of both samples and standards. These requirements are readily fulfilled in a laboratory engaged, for example, on routine foundry control of a few specified alloys, but present considerable problems when analysis is required of a wide variety of materials for which no standards are available, and which may be in all forms and conditions from a massive casting to a thin rolled foil or a powder.

Methods in which samples are first converted to a solution or powder form offer great advantages in these cases. The effects of metallurgical condition and shape of sample are eliminated and, by using synthetic standards, the need for a large range of expensive, chemically analysed metallic standards is avoided. Furthermore, controlled additions can easily be made to samples in solution, permitting the use of more efficient internal standard elements or buffers to minimise matrix effects.

A large number of methods of this type have been described in the literature and a previous Association report¹ discussed two methods which had been found to be useful by a Panel set up to investigate the possibilities of solution methods. Since that time, new methods, using the porous-cup electrode and rotating disc electrode have been introduced, and this report describes the applications of solution and powder methods at present in use in the Association's spectrographic laboratory.

Choice of Method

The methods in use in the Association's spectrographic laboratory are listed as follows:—

(a) The porous-cup method, which was first described

by Feldman² and later by Young and Berriman³. The solution is loaded into a graphite cup with a thin porous base and a spark is passed between the base and a counter electrode.

(b) The copper-cup method was described in a report of the Panel referred to above¹. The solution is placed in a small copper cup and a spark is passed to the liquid surface.

(c) The powder spark was first described by Milbourn and Hartley⁴ and later by the Solution Methods Panel¹. Samples are dissolved, converted to oxide and ground to a powder, which is placed in a graphite cup. A condensed spark is passed to the powder which sprays up into the discharge.

(d) The powder arc method has been described for the determination of trace impurities in copper alloys^{5, 6}. The samples are converted to salts and excited in a crater in the lower electrode of a D.C. graphite arc.

(e) The rotating disc method was first described by Harvey⁷. A graphite disc rotates with its lower edge dipping into the solution and a spark is passed between the wetted upper edge and a counter electrode.

(f) The flame method has been widely used for many years, but the spray and burner equipment is based on the paper of Robinson and Ovenston⁸.

(g) The impregnated electrode has been described by a number of workers, but the procedure of Muir and Ambrose^{9, 15} has been closely followed. A graphite electrode is heated in a furnace to make it porous and is then impregnated with the solution and sparked.

The choice of method to be used for a particular analysis is determined by consideration of the following factors.

1. Solubility of Sample.

If the sample is only partially soluble in acid and complicated separations and fusions are undesirable,

* B.N.F.M.R.A. Report B.R.A.1088P. The work described in this paper was made available to members of the British Non-Ferrous Metals Research Association in a confidential research report issued in November, 1954.

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then methods (a) and (f) are not suitable, as the insoluble component will clog the cup in the former and the spray jet in the latter. Methods (b), (e) and (g) are applicable, provided that an estimate of the insoluble material is not required; for example, boron may be determined by method (b) in a silicon-bearing aluminium alloy dissolved in nitric acid in which the silicon is insoluble. Methods (c) and (d) are applicable to materials of this description, which the acid treatment only partially dissolves, since the subsequent drying out and grinding will homogenise the sample.

2. Elements to be Determined.

Methods (a), (c), (d), (e) and (g) use graphite electrodes in some form, and are not suitable for the determination of small amounts of boron, calcium, magnesium, sodium and titanium, since these are present in ordinary purity graphite in varying amounts which make it difficult to assess the blanks. High purity graphite is much better in this respect but its price precludes its use to any extent. The determination of the above elements is therefore usually made by method (b), with the alternative of using the flame method for sodium determinations.

3. Sensitivity Required.

In general the true solution methods (a), (b), (e) and (f) are less sensitive than those in which the sample is introduced in solid form as in (c) and (d), where a much greater weight of the materials is introduced into the discharge. The impregnated electrode method (g) is intermediate in sensitivity since, although the sample is introduced as a liquid, by the time the discharge passes it has dried out and it is then possible to use arc-like excitation, which is impracticable where the sample is present as solution. In order of increasing sensitivity the methods may be placed thus: (b), (a) and (e), (c) and (g), (d). In this laboratory the flame method has been confined to the determination of sodium in various materials where its sensitivity is adequate ($< 1 \text{ p.p.m.}$).

4. Accuracy Required.

Favourable reports of reproducibilities of better than 3% by the porous-cup method have been confirmed in this laboratory for certain determinations and, when suitable in other respects, this method is preferred. The copper-cup method has also given reproducibilities of better than 5% of content, but it suffers from the disadvantage of the presence of a strong copper spectrum and background superimposed on the sample spectrum. The powder spark has been found to give coefficients of variation of 5–10% of content but the powder arc is seldom considered to be better than 25%, although this is usually on trace contents much less than 0.01%. Few applications have been made of the rotating disc or the impregnated electrode methods, but a full description is included, as limited tests have shown reproducibilities of the same order as those obtained by the porous-cup method.

A large number of determinations has been made using the above methods, selected according to the requirements of the particular problem. These are summarised in the Appendix at the end of the present paper. The common feature of all the methods is the initial conversion of the sample to solution or powder form, and the following section shows the general approach to this problem.

Conversion of Sample to Solution or Powder and Preparation of Standards

In general, nitric acid is favoured as a solvent since its salts can readily be ignited to oxides and are generally not volatile. However, other acids are used, and sometimes the formation of volatile salts can be used to advantage; for example, in the determination of sodium in aluminium by the flame method, an improvement in sensitivity by a factor of two or more is obtained by dissolving the sample in hydrochloric acid instead of nitric acid. Wherever possible analytical purity reagents are used and an acid blank is always included if its purity with respect to the element being determined is suspected. It has been found very important to maintain acid contents of samples and standards at the same level as far as possible. Although special treatments are sometimes required, the general methods of solution are as follows:—

Aluminium and its Alloys.

A suitable working strength is 20 g./litre. A 1 g. sample, preferably in a finely divided form, is taken up in 25 ml. concentrated nitric acid, with the addition of a few drops of mercuric chloride solution, and the resulting solution is made up to 50 ml. This acid will not dissolve the silicon present but, if determination of this element is not required, the insoluble residue may be ignored. However, if a silicon estimation is necessary, or if from other considerations it is desirable to use the porous-cup method, then the cloudy solution should be transferred to a polythene beaker and a few ml. of hydrofluoric acid added to dissolve the silicon residue. Solutions containing hydrofluoric acid should be made up and stored in polythene vessels, and can be conveniently measured out and transferred to the electrodes by means of calibrated P.V.C. or polythene dropping tubes.

Copper and its Alloys.

The working concentration for the determination of impurities is 100 g./litre, but for the determination of major constituents (i.e., $> 1\%$) 10 g./litre may be more suitable. For the concentrated solutions it is usual to take up a 5 g. sample in 25 ml. concentrated nitric acid and make up to 50 ml. with water, but when the samples contain appreciable amounts of tin, such as 85/5/5 gunmetals and 90/10 tin bronzes, then a mixture of equal parts of hydrochloric and nitric acids is used.

In some cases silicon or other metals such as niobium, zirconium, titanium, vanadium and chromium have been present in amounts up to 1% and a mixture of 6 ml. hydrofluoric acid, 6 ml. hydrochloric acid, and 15 ml. nitric acid has been found satisfactory for making up 5 g. samples to 50 ml. solution.

For the determination of trace impurities in copper and its alloys the powder-arc method is needed for its high sensitivity, and the solutions are evaporated to crystalline form beneath radiant heating lamps before grinding and excitation. Complete ignition to oxide is not carried out owing to danger of losing trace elements. Larger amounts of 0.02–5% of lead and tin have been determined in copper slags by the powder spark method on the oxides obtained by a preliminary partial digestion in nitric acid followed by evaporation, ignition to oxide and a thorough grinding in an agate mortar.

Lead and its Alloys.

For the determination of low constituents ($<0.1\%$) a suitable solution concentration is 100 g. lead in 1 litre of 20% nitric acid, but for amounts $>0.1\%$, 20 g./litre is usually sufficient. For example, for the determination of antimony in Alloy B (0.8% Sb) a 1 g. sample is dissolved in 25 ml. 20% nitric acid and made up to 50 ml. with the addition of 2-3 g. tartaric acid to prevent precipitation.

Other Materials.

Many other materials such as cobalt, titanium and zinc samples have been analysed by solution methods, and the individual acid treatments are indicated in the Appendix.

Analytical Procedures

This section describes in detail the various methods of sparking the solutions or powders, and includes the preparation and mounting of the electrodes.

(a) The Porous-Cup Electrode Method.

The porous-cup electrode method, in which the solution is placed in a graphite cup with a thin porous base, was first described by Feldman². The cup is made the upper electrode and a spark is passed between the solution, as it seeps through the base, and a graphite counter electrode. A great advantage of the method is its cleanliness, without the need for complicated screening from acid spray.

Porous-Cup Electrode.—This is machined from 6.5 mm. diameter graphite rod to the dimensions shown in Fig. 1a by using the cutter shown in Fig. 1b. This consists of a $2\frac{1}{4}$ in. length of silver steel A, with a $\frac{1}{8}$ in. hole drilled down the centre and a 6.5 mm. hole drilled to a depth of $\frac{3}{4}$ in. in one end. A $\frac{1}{8}$ in. drill is fixed in position by the grub screw E and is adjusted by means of the jig C so that its point is inset 0.8 mm. from the flat face F which is hardened. The shaper is cut away at B to allow graphite dust to escape and to facilitate the extraction of the finished cup. The operation of making a cup consists in pushing a piece of standard 6.5 mm. diameter graphite rod into the cutter, which can conveniently be rotated in a lathe chuck, until it comes up against the bottom of the 6.5 mm. hole, taking care to clear the drill just before reaching the bottom. On releasing the graphite rod it will spin round with the cutter and a cut can be made in it with a knife at about 1 mm. from the face F. The cutter is stopped and the excess graphite is broken off at the mark. The protruding part of the cup can then be cut off smoothly and flush with the face F using the knife. The finished cup is ejected by pushing at the end showing in the aperture B and loose graphite can be tapped out. With care, cup bottom thickness should not vary by more than ± 0.002 in.; variations in base thickness can have a marked influence on the spectra of the solutions^{10, 11}. An improved cutter is being developed which will enable the base thickness to be maintained constant, without undue precautions, to within ± 0.001 in., and this will form the subject of a later note.

The base of the cup is rendered porous before use by heating to redness in a blow-pipe flame, and it has been found advisable to use cups within 5-6 hours of this treatment as delay of a day or more seems to cause loss of porosity, which can however be restored by reheating.

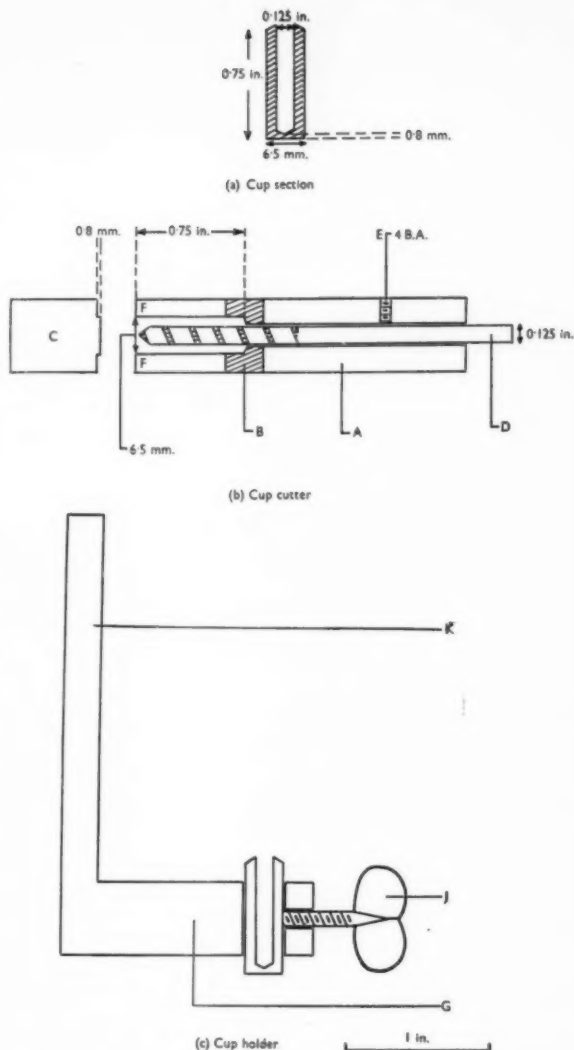


Fig. 1.—Apparatus for porous-cup electrode method.

The cup is held in a stainless steel holder shown in Fig. 1c, consisting of a 3 in. length of $\frac{1}{4}$ in. diameter rod K which is held in the top arm of the Gramont spark stand, and to which is brazed at right angles a $1\frac{1}{2}$ in. length of $\frac{1}{2}$ in. diameter rod G. In the end of G is a 6.5 mm. diameter hole in which the cup is held by means of the stainless steel wing screw J.

0.1 ml. of solution is loaded into the cup immediately before sparking by means of a small-bore pipette reaching to the bottom of the cup to avoid air entrapment. Each cup is used once only.

Counter Electrode.—This is of 6.5 mm. diameter graphite rod with an end shaped to a 30° point, with a well-rounded tip, in a rotating cutter, shown in Fig. 2. The graphite shaper is provided with a range of interchangeable cutters for different types of shallow cups and points used in other methods on the two standard sizes of graphite rods, 6.5 and 10 mm. diameter.

The shaper consists essentially of a guide drilled to take the stock size graphite rods and with a cutter mounted centrally inside, as shown in Figs. 2b and c.

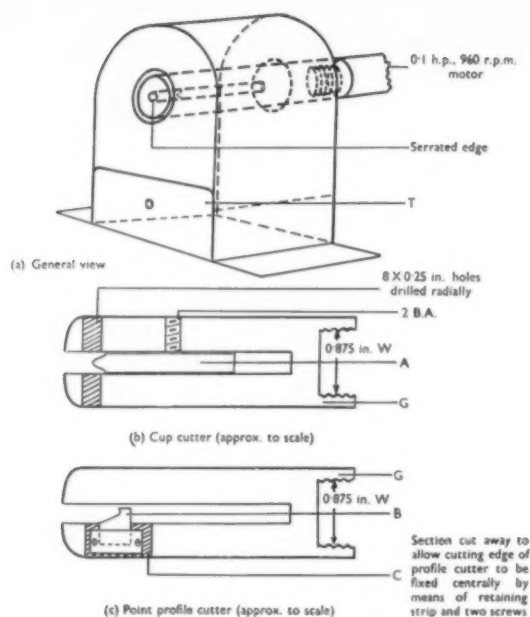


Fig. 2.—Graphite shaper.

The cup cutter, see Fig. 2b, consists of the guide *G* carrying a $\frac{1}{4}$ in. diameter steel rod *A* with a hardened cutting tip shaped to the profile of the cup required. A series of $\frac{1}{4}$ in. diameter holes drilled in the guide at the point where cutting occurs, allows ejection of the graphite powder. The point cutter is of the form shown in Fig. 2c where the guide *G* is cut away at *C* to give a flat surface to which is fixed a flat cutting blade *B*, by means of a retaining strip and two screws. The edge of the blade is ground to the tip profile required and is adjusted so that the plane of the cutting edge passes through the axis of rotation. The cutters are mounted on the shaft of a $\frac{1}{10}$ h.p., 960 r.p.m. motor by means of a $\frac{1}{8}$ in. Whitworth thread. A removable sheet metal screen, shown in Fig. 2a, retains the graphite dust thrown out from the cutter and collects it in the tray *T*.

Occasionally batches of graphite are received which are slightly above normal size, but the excess can be removed, on feeding into the cutter, by making a sharply serrated edge on the cutter guide as indicated in Fig. 2a.

Excitation.—The original Feldman method specified a simple condensed spark discharge, but in the Association's laboratory a General Purpose Source Unit¹² has been used with 20 mfd, 4 ohm, 0.25 mH. Attempts to use a more arc-like condition to increase sensitivity result in boiling of the solution in the cup, although an increase to 40 mfd is admissible. In some cases an improvement in sensitivity has been observed when the cup is made the negative electrode.

Exposure.—A loading of 0.1 ml. solution will normally last for at least 45 seconds, and at the end of this time there should still be some evidence of liquid on the cup base.

(b) The Copper-Cup Method.

This method was developed in the Association and has been described in detail in an earlier paper¹. For

convenience, however, part of this paper relating to the apparatus is included in the present report. Approximately 0.1 ml. of solution is transferred to a metal or graphite cup which forms the lower electrode of a pair between which an intermittent discharge is passed. The discharge may be generated by a simple condensed spark unit or by an intermittent source such as the B.N.F. General Purpose Source Unit. The discharge causes part of the solution to enter the gap as a fine spray. Some solution remains in the cup at the end of the exposure.

Apparatus.—A simple form of apparatus which has been found convenient to operate and maintain is shown in Fig. 3. The lower electrode holder *G* is a 4 in. length of $\frac{3}{8}$ in. diameter stainless steel rod, the upper end of which is drilled and slit to form a spring grip for the short cup electrodes, 7 mm. in diameter, which are normally employed. The upper electrode holder *F* is a similar length of $\frac{3}{8}$ in. diameter stainless steel tube, with its lower end split and sprung to grip 7 mm. diameter rod electrodes. A screw *S* serves to hold electrodes of smaller diameter. The two electrode holders are gripped in a Gramont stand and carry rubber bungs as indicated in the figure. The lower bung *I* is fitted with a drain-tube *E* and an initiating point *O*, which is necessary when working with the General Purpose Source Unit. This bung supports a glass shield *P* which prevents liquid or corrosive material from falling upon the spectrograph or associated equipment. The shield, a 3 in. length of $2\frac{1}{2}$ in. diameter Pyrex tube, is fitted with a 1 in. length of $\frac{3}{8}$ in. diameter tube *T*, seen in section in the figure, which provides an open path between the discharge and the spectrograph. A small side tube *D* is connected to an exhaust fan, which draws air in through *T* so that spray does not drift out. The upper bung *H* has a concentric groove cut in its lower surface to fit over the upper rim of the tube *P*, so sealing the chamber when the arms of the Gramont stand are racked together.

The lower arm of the stand can be swung out in a horizontal arc against a stop and, in this position, the apparatus is easily washed out and the electrodes readily changed. Fresh cups are inserted into the spring-clip and pushed down by the ebonite jig *K*, so that they are located exactly in the orifice *T* on the axis of the spectrograph. The upper electrode is located with the aid of the same jig or by using the normal optical projection system.

Electrodes.—High-purity copper electrodes have generally been used. The cup *A* is normally a short length of 7 mm. diameter rod, drilled concentrically to provide a hole 5 mm. in diameter and 6 mm. deep. The counter electrode *B* is a similar rod, machined to a conical tip of angle 30° . Both electrodes, when of copper, are cleaned after each exposure by pickling in nitric acid and rinsing well in water. They can be used a number of times before being re-shaped. Alternatively, a copper cup and graphite counter-electrode has been used, as has also a graphite cup and counter-electrode. For some types of analysis, a cup having a central pillar, the top of which projects about 0.5 mm. above its rim, has been found advantageous in ensuring steady running of the discharge.

Excitation.—Spectra are excited either by a simple condensed-spark circuit or by an intermittent arc-discharge such as is provided by the B.N.F. General

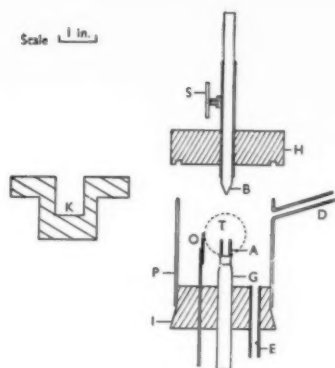


Fig. 3.—Apparatus for copper-cup method.

Purpose Source Unit or by the Kingsbury-McLelland circuit¹⁶.

Exposure.—A loading of 0.1 ml. solution will normally last at least 60 seconds, and exposure should not exceed the period in which some solution is left in the cup.

(c) *The Powder Spark Method.*

The powder spark method has been described elsewhere by Milbourn and Hartley⁴ but, for convenience, practical details are given below. Ground oxides of the sample are loaded into a graphite cup and a condensed spark is passed to the powder surface causing the powder to be sprayed up into the discharge. The method has been found particularly useful in the analysis of materials such as slags, which are difficult to dissolve.

Electrodes.—The lower electrode of 6.5 mm. diameter graphite is cut to form a cup $\frac{1}{4}$ in. deep and $\frac{3}{16}$ in. diameter, in a cutter of the type described in a previous section and illustrated in Fig. 2b. For lighter powders a $\frac{1}{4}$ in. diameter cup in a 1 cm. diameter rod should be used. The powder sample should be finely ground and packed loosely into the crater. The counter-electrode is a $\frac{1}{4}$ in. diameter conical tipped graphite rod, as used for the porous-cup method.

Excitation.—The original paper specified the use of a simple condensed spark and this procedure has been followed. Suitable conditions are 0.005 mfd, and 0.06 mH. with a 3 mm. spark gap.

Exposure.—This should not normally exceed 60 seconds, after which period a small amount of material still remains in the cup.

(d) *The Powder Arc Method.*

The use of this method has been confined to the determination of trace elements, where its poor reproducibility is of less consequence. Typical applications have been described in unpublished Association reports^{5,6} where its high sensitivity enables the determination of traces of lead and bismuth to 0.0005% or less in copper alloys.

Electrodes.—The lower electrode of 1 cm. diameter graphite is cut in a shaper of the type shown in Fig. 2b to form a shallow 3 mm. deep cup into which the crystals, dried out from an initial acid solution, are loaded. Samples may be converted to dry oxide before excitation providing there is no risk of losing volatile constituents by ignition. The counter electrode is a round-tipped conical 1 cm. diameter graphite rod cut in a shaper of the type shown in Fig. 2c.

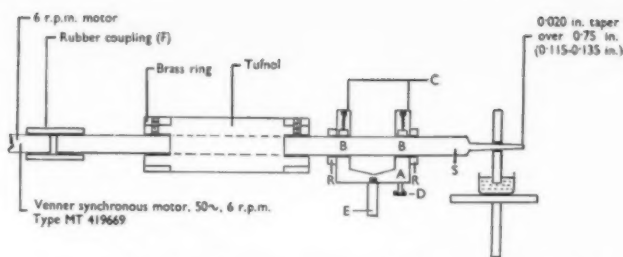


Fig. 4.—Rotating disc attachment (approximately to scale).

Excitation.—A 7 amp. D.C. arc is passed and the sample in the crater is made positive to obtain the maximum sensitivity on such elements as lead, bismuth and tin.

Exposure.—A single loading will burn for approximately 30 seconds.

(e) *The Rotating Disc Method.*

This was first described by Harvey.⁷ A disc of graphite is mounted on a stainless steel spindle and made the lower electrode. It is rotated in a vertical plane so that its lower edge dips into the solution under test and a spark is passed to the wetted upper edge from a graphite-counter electrode. In this laboratory the method has not been used to any extent, but has given promising results on the determination of zinc in brass and of some impurities in nickel plating solutions. The method is especially suited to the analysis of more viscous liquids such as oils.

Electrodes.—The arrangement of the electrodes is shown in Fig. 4. The graphite disc is 1 in. diameter and $\frac{1}{8}$ in. thick, and is mounted on the tapered stainless steel spindle S. The spindle turns in a $\frac{1}{4}$ in. hole drilled in the 1 in. square brass block A, shown in section. To cut down friction on S, a $\frac{5}{8}$ in. hole is drilled vertically into the block to leave the two plain bearings B. The spindle is held in position by the two retaining rings R and is insulated from the synchronous motor drive by the Tufnol extension T. Electrical contact to the block is made at the terminal D and, in turn, contact to the spindle is by means of the two spring-loaded carbon brushes C.

In operation, the block is clamped in the lower arm of the arc stand by means of the rod E, and adjusted so that the disc rotates in a vertical plane passing through the optical axis of the spectrograph. The lower edge of the disc dips into the solution held in a silica boat, supported on an adjustable table, which can conveniently be provided by fixing a piece of ebonite to the top of a standard Hilger Barfit lens mount. The counter electrode of round tipped conical graphite rod is held in the top arm of the stand above the disc, and the gap width and position are adjusted in the usual way.

The coupling to the synchronous motor, giving 6 r.p.m., can conveniently be made by means of a short length of rubber tubing F, which allows flexibility in the drive.

Graphite discs can be easily prepared on a small lathe by drilling a $\frac{1}{4}$ in. hole through the centre of a length of 1 in. diameter graphite rod and parting off $\frac{1}{8}$ in. thick slices by means of a tool fitted with a stop.

Excitation.—The rotating disc can be used with any spark-like source condition, as for the porous-cup

method. However, the method has the advantage that a more arc-like excitation, such as 240 mfd, 12 ohm, 0.25 mH on the General Purpose Source Unit, can be used, although there is a tendency with prolonged sparking under these conditions for the solution to boil in the dish. With a uni-directional discharge, less acid spray is obtained if the disc is made the positive electrode.

Exposure.—The method is economical in consumption of solution and a 5 ml. sample will give a large number of 30 second exposures, although there is a tendency for the overall spectrum intensity to increase if sparking is prolonged on a single disc.

(f) The Flame Method.

In the Association's laboratory the flame method has been applied to the determination of the alkali metals, mainly sodium in aluminium alloys. The apparatus* for the production of the spray and flame is essentially the same as that described by Robinson and Ovenston⁹. A coal-gas-air flame, with suitable water and mercury manometers respectively, has been used in conjunction with a Littrow spectrograph fitted with the direct-reading attachment designed by Naish¹³ and the integrator-recording circuit described by Naish and Ramsden¹⁴. This particular spray design suffers from the objection that the solution is used up at approximately 6 ml./min., most of it being wasted, and if a more efficient atomiser design could be devised it would have advantages.

(g) The Impregnated Electrode Method.

In various forms this type of solution method has been widely used, but in the Association's laboratory the technique described by Muir and Ambrose^{8, 15} has been followed. The method consists of impregnating a shaped graphite rod with the solution and sparking it against a graphite counter-electrode. The method has been used for the analysis of steels and has been found particularly useful for the determination of residual elements where an arc-like setting of the General Purpose Source Unit can be used to obtain the required sensitivity.

Electrodes.—The lower electrode consists of a $\frac{3}{4}$ in. length of $\frac{1}{4}$ in. diameter graphite with the end shaped in a cutter of the type shown in Fig. 2b to a conical cup 2 mm. deep. These electrodes are heated in a furnace to approximately 900° C. for a few minutes and then allowed to cool before use. The cups are pre-sparked for 60 seconds to condition the surface, and 0.05 ml. of the solution is placed in the crater and allowed to soak in. It has been found that a fairly massive holder improves the absorption of the solution. Cup electrodes are used once only. The counter electrode is a $\frac{1}{4}$ in. graphite rod with a round tipped conical point.

Excitation.—A simple condensed spark or a spark-like setting of the General Purpose Source Unit can be used, although improved sensitivity is given by an arc-like condition (240 mfd, 12 ohm, 0.25 mH) and sample positive.

Exposure.—The single impregnation will last for up to at least 1 minute exposure with even an arc-like excitation.

* Obtainable from Laboratory Glassblowers Co., Valley Works, Lane End Road, Sanda, High Wycombe, Bucks.

Results and Conclusions

In the majority of cases no comparison of results obtained by spectrographic solution or powder methods and normal chemical analysis is possible as the latter are not available. However, a few specific examples will show the wide applicability and give some indication of the reliability of the methods. Details of the methods referred to appear in the Appendix together with information on the expected accuracy of the result.

1. Determination of Boron in Aluminium-Boron Hardeners.

Copper-cup methods using synthetic standards.

Sample		% Boron	
		Chemical	Spectrographic
1	Method (a)	0.59	—
	Method (b)	1.1	0.85
2	Method (a)	0.10, 0.14	0.11
3	Method (a)	0.10, 0.10	0.095
4	Method (a)	0.04, 0.05	0.055

2. Determination of Chromium in Chromium Bronze.

Copper-cup method using synthetic standards.

Sample	% Chromium	
	Chemical	Spectrographic
	(a)	(b)
1	1.37	1.83
2	2.17	2.17
3	1.96	2.40
4	0.51	0.56
		0.43

3. Determination of Sodium in Aluminium-Magnesium Alloy.

Flame method and direct comparison with synthetic standards without using an internal standard line. The following spectrographic results were obtained by using nitrate solutions but it has lately been shown that some improvement in sensitivity and accuracy can be obtained by using hydrochloric acid as the solvent, as shown in the Appendix.

Sample	% Sodium	
	Vacuum Distillation Method	Spectrographic
1	0.001	<0.005
2	0.002	<0.005
3	0.003	<0.005
4	0.006	0.010
5	0.060	0.063
6	0.030	0.037
7	0.060	0.058
8	0.0015	<0.005
9	0.025	0.027
10	0.035	0.038

4. Determination of Antimony in Alloy B Lead.

Porous-cup electrode method using synthetic standards.

Sample	% Antimony	
	Chemical	Spectrographic
1	1.02	1.01
2	0.87	0.865
3	0.81	0.805
4	0.70	0.695

5. Determination of Niobium in Soils.

Porous-cup electrode method using synthetic standards and a pre-chemical concentration procedure.

Sample	% Niobium Oxide	
	Mean of Several Chemical Results	Spectrographic
1	0.16	0.15
2	0.21	0.185
3	0.60	0.61

6. Analysis of Aluminium Powders.

Porous-cup electrode method using dissolved metallic standards for iron, silicon and manganese, and synthetic standards for zinc.

Sample	% Iron Chem. Spec.	% Silicon Chem. Spec.	% Manganese Chem. Spec.	% Zinc Chem. Spec.
1	0.47	0.50	0.48	0.44
2	0.40	0.36	0.14	0.18
3	0.28	0.20	0.08(8)	0.09
4	0.18	0.23	0.11	0.10
5	0.13	0.12	0.07(3)	0.15

The few examples quoted above show how spectrographic solution methods have become an established practice in all cases where, for various reasons, the conventional spark-to-solid techniques are not applicable. Each of the methods described above has its uses and limitations and where some methods, such as the porous-cup and copper-cup, have been well tried and tested, others, such as the impregnated electrode and rotating disc methods, have not been developed to the same extent.

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Appendix

In Table I some applications of the seven solution methods detailed in the main text are listed.

Under the heading "Treatment of Sample" only the acid attack is given; for the powder arc and powder spark methods this is followed by concentration and crystallisation or calcining techniques, which have already been mentioned.

The wavelengths quoted are from the M.I.T. Wavelength Tables (John Wiley & Sons, Inc., N.Y.; Chapman & Hall Ltd., London, 1939) with the exception of two copper lines 2651.7 and 2634.9 A.U. referred to by Shenstone (*Phil. Trans. Royal Soc. Lond. [A]* 241, No. 832, 297-322, 1948).

The index point on the working curve is quoted wherever a line ratio has been plotted. In some instances the index point has been obtained by extrapolation and where this occurs the I.P. value is followed by "ex."

"Estimated accuracy" has been calculated for triplicate spectra unless otherwise stated and is:—

$$\frac{2}{\sqrt{n}} \times \sigma \times \frac{100}{m} \text{ i.e., the probability of an error exceeding the quoted accuracy is } 1 \text{ in } 20.$$

where n = number of spectra

σ = standard deviation

m = mean value of the determinations.

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TABLE I.—APPLICATIONS OF SPECTROGRAPHIC SOLUTION METHODS AT B.N.F.M.R.A. (See Appendix for Comments on the Information Given).

Alloy	Elements Determined	% Range Covered	Treatment of Sample	Method	Excitation Conditions	Exposure and Plate	Lines Used	Index Point	Estimated Accuracy %
ALUMINIUM C.P. Al	Fe Si Mn Zn Cu	0.05-0.8 0.05-0.7 0.002-0.2 0.5-1.5 0.005-0.2	1g. in 50ml. (25ml. HNO ₃ and few drops mercuric chloride solution and few drops of HF)	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0.25 mH.	5/30 on K.B.10	Al 2269.2 Fe 2756.5 Mn 2593.7 } BG Si 2516.1 } corrected Cu 3274.0 Zn 3345.0	0.14 0.018 0.18 0.022 0.46	±10 ±10 ±20 ±15* ±6 ±3
C.P. Al	Na	0.001-0.2	1g. in 50ml. 50% HCl	Flame	Coal gas pressure 5 cm. water Air pressure 30 cm. Hg	30 sec.	Na doublet 5890/96 (no internal standard used)	—	±3
Al/B Hardener	B	0.005-1.0	1g. in 50ml. 50% HNO ₃	Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0.25 mH	5/60 on K.B.10	Al 2652.5 } BG B 2496.8 } corrected	0.54	±10
Al/Be Hardener	Be	0.5-2.0	" " "	P.C.E.	Sample +ve G.P.S.U. 20μF., 4 ohm, 0.25 mH.	0/30 on K.B.10	Al 2660.4 Be 2650.6	0.40 ex.	±3
Al 10Mg (D.T.D.300)	B	0.005-0.1	" " "	Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0.25 mH.	5/60 on K.B.10	Al 2669.2 } BG B 2496.8 } corrected	0.009	±15
Al 3Cu, 5Si (D.T.D.424)	B	0.005-0.1	" " "	Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0.25 mH.	5/60 on K.B.10	Al 2669.2 } BG B 2496.8 } corrected	0.018	±15
Al 3Cu, 5Si (D.T.D.424)	Zn	1.0-10.0	" " "	Cu Cup	Sample +ve G.P.S.U. 60μF., 4 ohm, 0.25 mH.	5/30 on K.B.10	Al 2652.5 Zn 3302.9 BG corrected	0.68 ex.	±10
Al 4Cu, 2Ni, 1.5Mg (Y Alloy)	B	0.02-0.2	" " "	Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0.25 mH.	5/60 on K.B.10	Al 2660.4 } BG B 2496.8 } corrected	0.034	±15
Al 10Mg (D.T.D.300)	Na	0.005-0.2	" " "	Flame	Coal gas pressure 5 cm. water Air pressure 30 cm. Hg	30 sec.	Na doublet 5890/96	—	±10
Al 10Mg (D.T.D.300)	Be	0.001-0.5	" " "	P.C.E.	Sample +ve G.P.S.U. 20μF., 12 ohm, 0.25 mH.	0/60 on K.B.10	Al 3050.1 Be 3131.1	0.0023	±10
CHROMIUM Chromium Plating Solutions	Si	0.05-0.5 g./litre Si	No treatment	Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0.25 mH.	5/50 on K.B.10	Cr. 2512.0 } BG Si 2516.1 } corrected	0.08	±13
CORAL Cobalt Powder	Pb, Zn	0.003-1.0	1g. in 100ml. 50% HNO ₃	P.A.	Sample +ve D.C. Arc 7A	0/30 on K.B.10	Cu 2833.9 Pb 2833.1 } BG Zn 3302.9 } corrected Zn 2138.6	0.023 > 1.0 ex.	±25 ±30

* Cu does not always give results consistent with chemical analyses.

Table continued on next page]

TABLE I—Continued

Alloy	Elements Determined	% Range Covered	Treatment of Sample	Method	Excitation Conditions	Exposure and Plate	Lines Used	Index Point	Estimated Accuracy
COPPER									
Copper	Pb	0-005-0.3	1g. in 10ml. 50% HNO ₃	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/30 on K.R.10	Cu 2858-2 } BG Pb 2833-1 } corrected	0-1	± 5
Copper	Ba	0-002-0.1	" " "	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/60 on K.R.10	Cu 2319-6 } BG Ba 2355-3 } corrected	0-031	± 10
Copper	Pb, Bi	0-001-0.1	" " "	P.A.	Sample +ve D.C. Arc 7A	0/25 on K.R.10	Pb 2833-1 } BG Bi 3067-7 } corrected	—	± 25
B Mg/Cu Hardener	B, Mg	0-25-5.0 0-025-0.5	" " "	Cu Cup	Sample +ve G.P.S.U. 60μF., 4 ohm, 0-25 mH.	5/15 on K.R.10	Cu 2618-4 B 2496-8 Mg 2795-5	3-9 0-098	± 20 ± 20
Pb Ni/Cu Hardener	Pb, Ni	0-1-1.0	" " "	Cu Cup	Sample +ve G.P.S.U. 60μF., 4 ohm, 0-25 mH.	5/50 on K.R.10	Pb 2814-2 } BG Ni 3054-3 } corrected	—	± 20 ± 15
Copper	B, Cu, Mg	0-005-0.3	" " "	Cu Cup	Sample +ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	5/60 on K.R.10	Cu 2951-3 } BG B 2496-8 } corrected Ca 4226-7 Mg 2790-8	0-071 0-061 0-04	± 15
Copper	Mn, Cd, Pb, Ni, Ag, Cr, Fe, Bi, Al	0-005-0.2	" " "	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/30 on K.R.10	Cu 2634-9 Mn 2949-2 Cd 2288-0 Pb 2833-1 Ni 3050-8 } BG Ag 3382-9 } corrected Cr 2835-6 Fe 2756-3 Bi 3067-7 Al 3861-5 Pb 2833-1 } BG	0-0080 0-0066 0-0070 c.0-06 c.0-075 0-0058 0-0175 c.0-04 >0-02 ex.	± 5 ± 10 ± 15 ± 20 ± 40 ± 5
60 Cu, 40 Zn Brass	Pb	0-005-1.0	" " "	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/30 on K.R.10	Pb 2833-1 } BG Cu 2882-9 } BG Fe 2866-9 } corrected	1-37	± 4
"	Fe	0-25-5.0	" " "	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/30 on K.R.10	Cu 2319-6 Sb 2311-5 Cu 2548-8 Zn 2502-0	0-071 28-3	± 50 ± 3
"	Sb	0-001-0.2	" " "	P.A.	Sample +ve D.C. Arc 7A	0/30 on K.R.10	Cu 2544-8 Zn 2502-0 Cu 2858-2 Be 2494-6	26-5 0-062	± 3 ± 15
Brass	Zn	25-45	1g. in 100ml. 20% HCl + HNO ₃ (1:1 acid ratio by vol.)	P.C.E.	Condensed spark, 0-005μF., 0-0 mH 15 K.V. peak	0/60 on K.R.10	Background Li 6707-8 Cu 2951-3 Cu 2348-8 Bi 3067-7 Pb 2873-3 Sn 2863-3 Ni 3050-8 Fe 2966-9 Mn 2953-1 Cd 2265-0	c.0-003 ex. 0-13 c.0-01 ex. c.0-004 ex. c.0-025 ex. c.0-0025 ex. c.0-016 ex.	± 6 ± 7 ± 9 ± 11 ± 13 ± 13
76 Cu, 22 Zn, 2 Al (Al Brass)	Be	0-01-1.0	1g. in 10ml. 50% HNO ₃	Rotating Disc Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0-25 mH.	10/20 on K.R.10 5/40 on K.R.10	Li 6707-8 Cu 2951-3 Cu 2348-8 Bi 3067-7 Pb 2873-3 Sn 2863-3 Ni 3050-8 Fe 2966-9 Mn 2953-1 Cd 2265-0	26-5 0-062	± 3 ± 15
90 Cu, 10 Al (Al Bronze)	Li	0-005-0.1	" " "	Cu Cup	Sample +ve G.P.S.U. 120μF., 12 ohm, 0-25 mH.	2/60 on L.L.R.S.P.	Background Li 6707-8 Cu 2951-3 Cu 2348-8 Bi 3067-7 Pb 2873-3 Sn 2863-3 Ni 3050-8 Fe 2966-9 Mn 2953-1 Cd 2265-0	c.0-002 c.0-0081 ex. c.0-04 ex. c.0-09 ex. c.0-004 ex.	± 20 ± 16 ± 30 ± 24 ± 28
60 Cu, 40 Zn (Brass)	Pb, Bi, Fe, Ni, Mn, Cd, As, Sb, P	0-1-0.4 0-05-0.2 0-025-0.1 0-02-0.08 0-0125-0.05	1g. in 10 ml. 50% HNO ₃	P. Spark	Condensed spark, 0-005μF., 0-06 mH. 10 K.V. peak	0/50 on K.R.10	Li 6707-8 Cu 2951-3 Cu 2348-8 Bi 3067-7 Pb 2873-3 Sn 2863-3 Ni 3050-8 Fe 2966-9 Mn 2953-1 Cd 2265-0	c.0-003 ex. 0-13 c.0-01 ex. c.0-004 ex. c.0-025 ex. c.0-0025 ex. c.0-016 ex.	± 6 ± 7 ± 9 ± 11 ± 13 ± 13
90 Cu, 10 Al (Al Bronze)	Pb, Bi	0-0005-0.1 0-0005-0.01	" " "	P.A.	Sample +ve D.C. Arc 7A	0/30 on K.R.10	Li 6707-8 Cu 2951-3 Cu 2348-8 Bi 3067-7 Pb 2873-3 Sn 2863-3 Ni 3050-8 Fe 2966-9 Mn 2953-1 Cd 2265-0	c.0-0081 ex. c.0-04 ex. c.0-09 ex. c.0-004 ex.	± 16 ± 30 ± 24 ± 28
92 Cu, 8 Sn (Sn Bronze)	B	0-003-0.3	5g. in 6ml. HF + 6ml. HCl + 15ml. HNO ₃ made up to 30ml. with H ₂ O	Cu Cup	Sample +ve G.P.S.U. 60μF., 4 ohm, 0-25 mH.	5/60 on K.R.10	Cr 2851-4 Ti 2828-9 Zr 3438-2 B 2496-8 Nb 3195-0 V 3080-5 Cu 3454-6 Zr 3438-2 Cu 2651-7 Pb 2833-1 Bi 3067-7	± 45 ± 12	
90 Cu, 10 Sn (Sn Bronze)	B, Cr, Nb, V, Ti, Zr	0-01-1.0	" " "	Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0-25 mH.	5/60 on K.R.10	Cr 2851-4 Ti 2828-9 Zr 3438-2 B 2496-8 Nb 3195-0 V 3080-5 Cu 3454-6 Zr 3438-2 Cu 2651-7 Pb 2833-1 Bi 3067-7	± 45 ± 12	
93 Cu, 5 Ni, 1 Fe, 1 Mn	Zr	0-02-1.0	" " "	Cu Cup	Sample —ve G.P.S.U. 60μF., 4 ohm, 0-25 mH.	5/60 on K.R.10	Cr 2851-4 Ti 2828-9 Zr 3438-2 B 2496-8 Nb 3195-0 V 3080-5 Cu 3454-6 Zr 3438-2 Cu 2651-7 Pb 2833-1 Bi 3067-7	0-125	± 12
93 Cu, 5 Ni, 1 Fe, 1 Mn	Pb, Bi	0-0005-0.1	1g. in 10ml. 50% HNO ₃	P.A.	Sample —ve D.C. Arc 8A	0/30 on K.R.10	Cr 2851-4 Ti 2828-9 Zr 3438-2 B 2496-8 Nb 3195-0 V 3080-5 Cu 3454-6 Zr 3438-2 Cu 2651-7 Pb 2833-1 Bi 3067-7	0-0006	± 30 ± 15 (based on 4 exposures)
70 Cu, 30 Ni (Monel)	Pb	0-001-0.2	" " "	P.A.	Sample +ve D.C. Arc 7A	0/30 on K.R.10	Pb 2833-1 } BG Pb 2873-3 } corrected Cu 2166-9 Cd 2144-4 Cu 2951-3 Pb 2401-9 } BG Pb 2833-1 } corrected Sn 2913-5 Sn 2863-3	0-40	± 7
99 Cu, 1 Cd (Cd Copper)	Cd	0-1-1.0	0-1g. in 10ml. 50% HNO ₃	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/30 on K.R.10	Pb 2833-1 } BG Pb 2873-3 } corrected Cu 2166-9 Cd 2144-4 Cu 2951-3 Pb 2401-9 } BG Pb 2833-1 } corrected Sn 2913-5 Sn 2863-3	c. 9-0 ex. 0-13 >10-0 ex.	± 9 ± 7
Copper Slags	Sn	0-05-10.0	0-2g. dissolved with 5ml. 50% HNO ₃ buffered 10:1 with CuO (diss. in HNO ₃)	P. Spark	Condensed spark, 0-005μF., 0-06 mH. 10 K.V. peak	0/30 on K.R.10	Pb 2833-1 } BG Pb 2873-3 } corrected Cu 2166-9 Cd 2144-4 Cu 2951-3 Pb 2401-9 } BG Pb 2833-1 } corrected Sn 2913-5 Sn 2863-3	0-51	± 3
LEAD									
Lead, 0-85 Sb (Alloy B)	Sb	0-5-1.5	1g. in 50ml. 10% HNO ₃ + 2-3g. tartaric acid	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/40 on K.R.10	Pb 2628-3 Sb 2598-1	0-51	± 3
NICKEL									
Nickel Plating Solutions	Mn, Fe, Cu	0-0004-0-002 0-001-0-02	Dilution 1:1 with distilled H ₂ O	P.C.E.	Sample —ve G.P.S.U. 20μF., 4 ohm, 0-25 mH.	0/30 on K.R.10	Ni 2648-7 Ni 2134-3 } BG Mn 2949-2 } corrected Fe 2598-4 Cu 2136-0	0-003 0-005 0-015	± 10 ± 20 ± 20
TITANIUM									
Al, Ti Alloys	Al	1-0-10.0	0-5g. in 25ml. 20% H ₂ SO ₄ + 3g. tartaric acid + a few drops mercuric chloride solution	Cu Cup	Sample +ve G.P.S.U. 60μF., 4 ohm, 0-25 mH.	5/50 on K.R.10	Ti 2662-0 } BG Al 2575-1 } corrected	3-3	± 5

Table continued on next page

TABLE I—Continued.

Alloy	Elements Determined	% Range Covered	Treatment of Sample	Method	Excitation Conditions	Exposure and Plate	Lines Used	Index Point	Estimated Accuracy %
ZINC Zinc	Mg, Li	0.005-0.1	1g. in 100ml. 50% HNO ₃	Cu Cup	Sample +ve G.P.S.U. 120 μ F., 12 ohm, 0-25 mH	5/20 on I.L.R.S.P.	Zn 2756.5 Mg 2852.1 Cu 5782.1 Li 6707.8 Zn 2670.5 Pb 2823.2 Cd 2288.0 Fe 2386.9 Al 3092.7 Cu 2192.3 Mg 2852.1	0.016 0.054	± 15 ± 20
Zinc Carbonate Filter Cake	Pb	0.2-2.0	4.8g. in 25ml. 50% HNO ₃	P.C.E.	Sample -ve G.P.S.U. 40 μ F., 1 ohm, 0-25 mH.	0/30 on K.B.10	BG corrected	<0.01 ex. 0.06 0.0034 0.008 ex. <0.001 ex.	± 17 ± 12 ± 22 ± 8 ± 14 ± 22
SOILS African Soil— Mainly Magnetite, Limonite and Apatite	Nb Ta	0.1-7.0 0.01-0.3	5g. specially treated: Mo added as internal standard	P.C.E.	Sample -ve G.P.S.U. 20 μ F., 4 ohm, 0-25 mH.	0/30 on K.B.10	Mo 2688.0 Nb 2698.8 Ta 2460.6	BG corrected 0.115 1.15 0.05 ex.	± 5 ± 10

* A copper line (from the electrodes) was used as an "internal" standard, as there was no suitable zinc line available.

Exhibits of Metallurgical Interest at the Physical Society Exhibition

The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.

Ultrasonic Flaw Detection

A FEATURE of the display of ultrasonic flaw detection equipment on the stand of Ultrasonoscope Co. (London), Ltd. (which is associated with Glass Developments, Ltd.), was a selection of probes exhibited in conjunction with the latest version of the Ultrasonoscope. The variable angle low frequency probes use barium titanate discs with a resonant frequency of 400 kc./s. and are intended for use on coarse-grained materials. They have been used successfully on copper and brass billets and also on refractory blocks. Examples of transverse wave probes shown are intended for use on thin sections down to $\frac{1}{16}$ in.

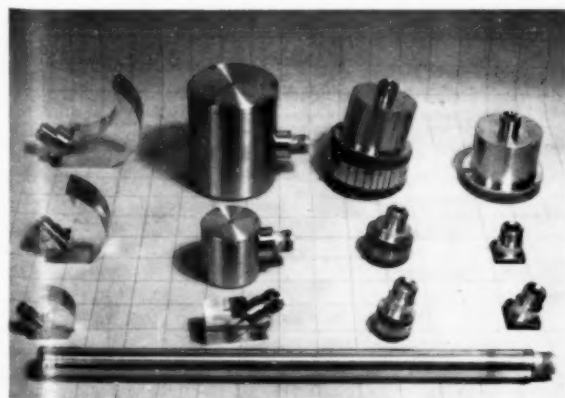
Of particular interest was the demonstration of ultrasonic flaw detection with the sample completely immersed in a liquid bath. This technique, in conjunction with sonoscope presentation, enables large areas to

be scanned quickly without the difficulties involved in conventional testing. The step function pulse technique which is being developed by the company is intended primarily for use on thin sections and can be applied to flaw detection, thickness measurement, and allied problems. The major limitation of the fundamental systems employing a damped train of waves is that the pulse duration is long compared with the time in which it is required to receive echoes back from close ranges. In the step function pulse technique a square wave is used, the duration of which is sufficiently long for echoes generated by the leading edge to arrive back before the trailing edge of the wave affects the receiver. In this way direct echoes can be obtained from as small a distance as 0.030 in. in aluminium or steel.

Portable Thermocouple Potentiometer

The portable thermocouple potentiometer shown by the Croydon Precision Instrument Co. is suitable for temperature measurement with all types of thermocouple and for calibrating the indicating instruments used with them. Two ranges are provided, 0-105 mV. for use with base metal couples, and 0-21 mV. for precious metal couples. The auxiliary potential divider included provides an adjustable potential which can be injected into external instruments for calibration purposes.

The potentiometer consists of a 3 in. diameter slide wire and a 21-position switch decade. Designed to eliminate contact thermo-e.m.f.s, the slide wire is of precious metal alloy. The decade dial has an all copper switch to minimise further such effects, and the resistance material is of selected manganin having a very low temperature coefficient and carefully aged before adjusting. The instrument includes a sensitive pointer galvanometer, a standard cell, and a three-position selector switch giving two test positions and a standardi-



A selection of Ultrasonoscope probes



Portable thermocouple potentiometer

sation position. A galvanometer sensitivity key is incorporated, which has three positions; max., 1/10 sensitivity, and an off position to which the key will always automatically return. The auxiliary potential source has coarse and fine adjustments and the potential injected can be measured on the potentiometer.

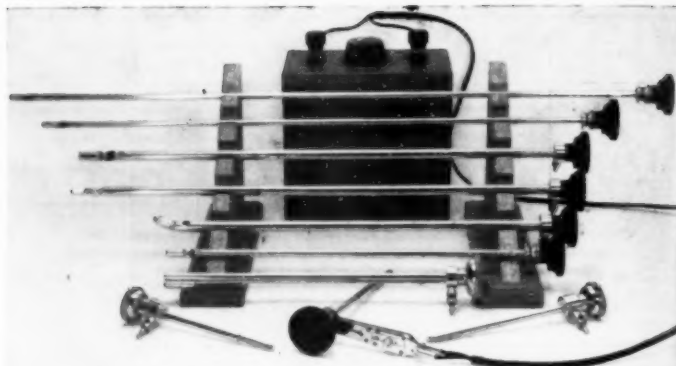
Flaw Detection

The non-destructive testing equipment shown by The Solartron Electronic Group, Ltd., has been designed to test ferrous and non-ferrous metals during a continuous process of manufacture, by taking automatic action to mark defective sections, or by informing an operator so that he may stop continuous flow of material in the case of serious flaws.

The basis of operation is the use of twin sensing coils which form two arms of a bridge detector. This is energised by an oscillator which can easily be set to a number of spot frequencies, any disturbance in the bridge being magnified by a selective amplifier and indicated on a monitor meter. In addition to this visual warning a relay circuit is incorporated which can be preset to any reasonable degree of sensitivity, giving a contact closure output upon unbalance occurring. This action may be utilised for operator warning or machine control, or for any special local purpose such as giving a remote indication at a production monitoring position.

Internal Inspection

The Introsopes shown by the Foster Instrument Co., Ltd., have become part of the standard inspection equipment in many industries, and provision is now being made at the design stage for the examination of normally inaccessible surfaces. They are self-illuminated telescopic optical instruments specially designed to give sharp close-up views. The optical system employed uses optically worked lenses and prisms and, according to the depths of insertion and angles of view required,



A range of Foster Introsopes

can be supplied with interchangeable sections and alternative objective heads. Among the instruments on show was one which uses a new method of inspecting the surface finish in the bore of small holes from $\frac{3}{16}$ in. diameter upwards. Another new model has been specially designed for drum and barrel inspection, where the operating conditions require flame-proof or intrinsically safe apparatus.

Combined Magnetic Stirrer and Hotplate

From their range of laboratory stirrers, J. W. Towers & Co., Ltd., showed a combined magnetic stirrer and hotplate. The stirrer utilises a rotating magnetic field to induce a vigorous rotary movement in a small magnetised bar totally enclosed in a polythene tube and placed in the liquid to be stirred. Varying degrees of agitation are possible, depending on the speed at which the external magnetic field is rotated. This can be controlled by a rheostat from approximately 100 to 1,200 r.p.m. Two polythene-enclosed magnet rotors are supplied, one $\frac{3}{4}$ in. long, and the other $1\frac{1}{2}$ in. long. Glass-enclosed rotors can be supplied as an alternative, if required. A 4 in. diameter cast aluminium alloy hotplate is supported by a panel of heat insulating material on the top of the case of the magnetic stirrer unit. This case accommodates the speed control for the stirrer motor and the Simmerstat control for the hotplate. The heating element has a loading of 250 watts and will attain a temperature of 200° C. Important features of this device, in addition to its stirring efficiency, are its convenience for use in closed systems where gas volume changes must be observed, moisture and air must be excluded, high vacuum pressure must be maintained, or micro-chemical procedures are involved; and the fact that only glass and polythene contact the liquid being stirred.

New Factory for Elcontrol

THE steadily growing demand for industrial electronic controls has caused Elcontrol, Ltd., to move into a new and much larger factory. Although they went into their present premises at Hitchin only $3\frac{1}{2}$ years ago, these are now quite inadequate and Elcontrol have accordingly taken a newly built factory next door to their present site, which will give them three times the floor area and will provide room for much needed development.

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